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THE DESTRUCTION OF RABBITS IN AUSTRALIA AND NEW ZEALAND.

Upon reading in *Le Temps* that the government of New South Wales had offered a prize of $125,000 for the discovery of a process for the extermination of the rabbits that have for some time past been devastating Australia and New Zealand, Mr. Pasteur wrote to that journal suggesting that chicken cholera be spread

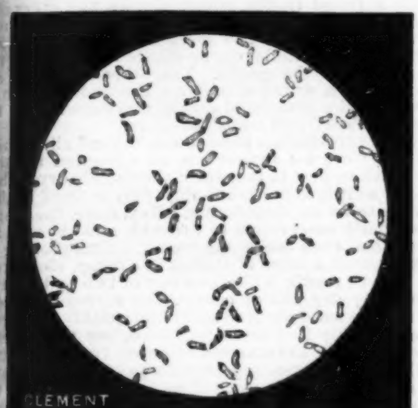


Fig. 1.—CHOLERA MICROBES.

among these animals, this disease being as fatal to rabbits as to domestic fowl.

"Immediately after sending this letter," says Mr. Pasteur in the *Annales de l'Institute Pasteur*, "I had the curiosity to try some direct experiments upon rabbits. I recalled the fact that chicken cholera is easily communicated to rabbits, but I had made no studies upon these rodents. I had often witnessed the death

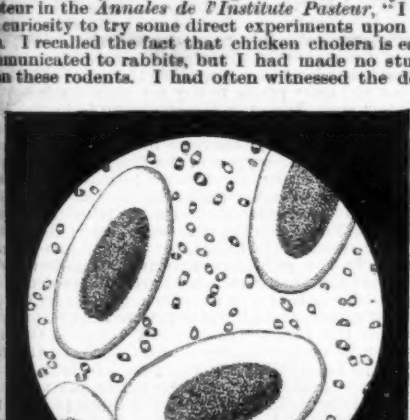


Fig. 2.—PIGEON'S BLOOD WITH CHOLERA.

of rabbits that had been placed in non-disinfected cages in which chickens had succumbed to the disease. It was a question to know (and one that has been solved affirmatively by several persons) whether chicken cholera is not simply the septicæmia of rabbits once studied by Dr. Davaine.

"I was soon assured of the facility with which the least food given to rabbits, after it had been contaminated by a culture of chicken cholera, rapidly caused the death of these rodents.

"The following are some of the experiments that I had performed by Mr. Loir, a student of medicine attached to my laboratory:

"On the 27th of November five rabbits were placed in a box, and were left therein until 6 o'clock p. m. without food. At this hour, 100 cubic centimeters of a virulent culture of chicken cholera were put into a basin, and some cabbage leaves were soaked therein. After these leaves had been allowed to drain, they were fed to the rabbits, which, in a few minutes, had finished their meal. At midnight three uncontaminated rabbits were placed with the others.

"On the 28th of November, at 8 o'clock a. m., the five injected rabbits appeared to be sick. At 11 o'clock two were dead, seventeen hours after their meal. The three others died in the afternoon, twenty-four hours after their meal.

"On the same day, at 7 o'clock in the evening, one of the rabbits that had been placed at midnight of the preceding day with those that had eaten the infected food was found dead. The two others did not become sick.

"On Saturday, December 3, at 5 o'clock p. m., some cabbage leaves upon which 10 cubic centimeters of a virulent culture of chicken cholera diluted with 100 cubic centimeters of sterilized water had been poured, were fed to four rabbits. At midnight all the food had disappeared, and four more rabbits were placed with the others.

"At 8 o'clock a. m. of the next day, two of the rabbits seemed to be languid. At 11 o'clock one was dead, at 2 o'clock two more were dead, and at 4 o'clock the last of those that had eaten succumbed. The bodies were left with the four animals that had been put into the box at midnight.

Fig. 4.—THE RABBIT PLAGUE IN AUSTRALIA.

"On the 5th of December, one of these rabbits was found dead, on the 6th another one, on the 7th a third, and on the 9th the fourth. All these rabbits were of the domestic variety.

"On the 17th of December 10 cubic centimeters of chicken cholera virus were placed upon a cabbage leaf and given to a rabbit from a warren. On the 18th it died.

"In all the preceding cases it was proved that death was really due to the microbe of chicken cholera.

"On the 3d of December and some days succeeding, experiments were made upon the following animals: pigs, dogs, goats, sheep, rats, horses, and asses—in all cases by contamination of the food. None of these animals was affected.

"This is not all. The action upon rabbits is so rapid, and there is so little need of multiplying the meals, that I am persuaded, in recurring to my old experiments on chickens, that the latter would not die if

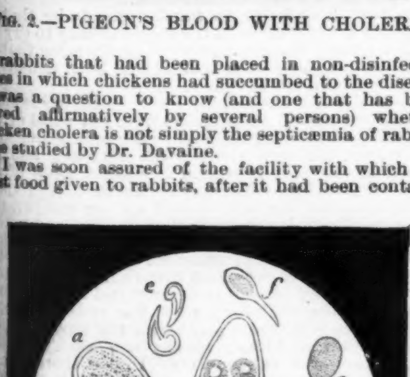


Fig. 3.—RABBIT'S BLOOD AFFECTED.

Fig. 5.—BODIES OF RABBITS KILLED BY THE MICROBE OF CHICKEN CHOLERA.

they were left on ground that the food of rabbits had partially contaminated; for they possess much less receptivity for the disease than rabbits do.

"In contact with the air, the microbe of chicken cholera quickly dies. It loses its virulence at 51° C., a temperature, it is said, that is sometimes reached in Australia in summer; but it would never be necessary to operate upon the rabbits in the full heat of midday.

"It is easy, on the contrary, to preserve the microbe of chicken cholera for several years by excluding the air from it. It will therefore always be possible to procure very virulent material. My former experiments, communicated to the Academy of Sciences, are a proof of this.

"Cultures of chicken cholera may be made in bouillons of any animal whatever. One of the cheapest would be that prepared from the flesh of rabbits.

"It results from the preceding experiments that not only do rabbits that have ingested food contaminated by the microbe die very quickly (in less than twenty-four hours), but that rabbits associated with those that have not taken the infected food likewise die in great number. I reserve the question of the mode of infection. That is a point that I shall examine later on.

"Is it true that the rabbits of one burrow do not mix with those of another? We may, without any apprehension for the success of the experiment, consider the case in which the rabbits of one burrow do not associate with those of another, and do not communicate the contagion to them after they have been infected. The disease is so easily communicated by food that, even though the contagion was not spread by infected rabbits to non-infected ones, the destruction of these animals would be none the less easy thereby.

"In my letter to *Le Temps*, I spoke of temporary barriers placed around the burrows. Such a complication would be useless. I would proceed on a large scale as follows: Around one or more burrows, I would mow down a certain quantity of grass, which would afterward be brought within reach of the rabbits by rakes before the animals came out in the evening. This grass, contaminated by a culture of chicken cholera, would be eaten by the rabbits as soon as they came across it. A barrier would be useless to stop them and force them to eat. . . .

"It was desirable that an experiment on a large scale might be made, and an accident soon offered the occasion to me under the most favorable conditions. Mrs. Pommery, of Reims, proprietor of the great champagne house that bears her name, sent me the following letter, after reading my note in *Le Temps*:

"SIR: Over my cellars at Reims I have a close of 16 acres entirely surrounded by walls. I conceived the unfortunate idea of putting rabbits therein to afford my grandchildren a city hunt. The animals have increased and mined the earth to such an extent that I wish to destroy them. Ferrets are powerless to start them from the huge piles of chalk in which they take refuge. If you would be willing to experiment on the process that you suggest for the destruction of these animals in Australia, I offer you the means of doing so.

MRS. POMMERY."

"Soon afterward I learned from my intelligent correspondent that, afraid of seeing the rabbits of her close, driven by hunger, prolong their subterranean galleries beyond measure and affect the stability of the cellar vaults, it had occurred to her to keep them in their burrows not far from the surface by daily furnishing them with a meal of lucern or hay distributed around the burrows. It will be seen from this how easy it was to attempt the destruction of the rabbits of Mrs. Pommery's close.

"On the 23d of December, I sent Dr. Loir to Reims to sprinkle the day's food with a recent culture of the microbe of chicken cholera. As usual, the food was consumed within a few minutes. The result was, so to speak, surprising. Mrs. Pommery wrote me on the 26th of December:

"Saturday morning . . . . nineteen dead rabbits were counted outside of the burrows. . . . Monday morning thirteen more dead were counted, and, since Saturday, not a single living rabbit has been seen about the grounds. Besides, a little snow had fallen during the night and not a sign of a rabbit's foot was to be seen around the piles of chalk."

"As a general thing, the rabbits died in their burrows. The thirty-two bodies found upon the surface of the close must therefore have represented a small minority among the dead, as will be presently seen. In another letter, written on the 27th, Mrs. Pommery says:

"The lucern . . . has not been touched again, and not a sign of a rabbit's foot has been seen in the snow. All are dead." . . .

"How many rabbits died in the burrows? It is difficult to know exactly. Mrs. Pommery informs me by a letter that I received January 5, that her workmen estimated the number of rabbits that daily ate the large bundles of hay that were distributed around their burrows at much more than a thousand.

"On another hand, adds Mrs. Pommery, everywhere that the hillocks of chalk, the usual dwelling place of the rabbits, are slightly uncovered, two, three, four, or five dead animals are found."

[We add to the foregoing note a few hitherto unpublished engravings. Fig. 1 shows the appearance of the microbes of chicken cholera greatly magnified, since their actual dimensions are one five-hundredth of a millimeter. Fig. 2 shows, under the same magnification, the blood of a pigeon afflicted with chicken cholera. It is remarkable to see that the bacillus has a very different form in the culture (Fig. 1) from that in the blood (Fig. 2). The two preparations that served for making these figures were made in the laboratory of Mr. Pasteur, and we are indebted for them to Dr. Roux, to whom we offer our sincere thanks.

Mr. Megnin proposes the inoculating of rabbits with a disease which is peculiar to them, viz., phthisis of the liver. Fig. 3 shows the appearance of the microbes of this disease highly magnified and in different stages of development.

Finally, we present two artistic compositions, one of which (Fig. 4) gives a correct idea of the abundance of rabbits in Australia, and the other (Fig. 5) represents the result of Mrs. Pommery's experiment. Our engraving, which is very accurate, is a reproduction of a photograph sent to us by Mr. L. Pommery, along with the necessary data.

The method recommended by Mr. Pasteur is soon to be experimented with in Australia, and will certainly give the results anticipated by our illustrious fellow countryman.—*La Nature.*]

[NATURE.]

TIMBER, AND SOME OF ITS DISEASES.*

By H. MARSHALL WARD.

V.

It has long been known that timber which has been felled, sawn up, and stored in wood yards is by no means necessarily beyond danger, but that either in the stacks, or even after it has been employed in building construction, it may suffer degeneration of a rapid character from the disease known generally as "dry rot." The object of the present paper is to throw some light on the question of dry rot, by summarizing the chief results of recent botanical inquiries into the nature and causes of the disease—or, rather, diseases, for it will be shown that there are several kinds of "dry rot."

The usual signs of the ordinary dry rot of timber in buildings, especially deal timber or fir wood, are as follows: The wood becomes darker in color, dull yellow-brown instead of the paler tint of sound deal; its specific weight diminishes greatly, and that this is due to a loss of substance can be easily proved directly. These changes are accompanied with a cracking and warping of the wood, due to the shortening of the elements as water evaporates and they part from one another; if the disease affects one side of a beam or plank, these changes cause a pronounced warping or bending of the timber, and in bad cases it looks as if it had been burnt or scorched on the injured side. If the beam or plank is wet, the diseased parts are found to be so soft that they can easily be cut with a knife, almost like cheese; when dry, however, the touch of a hard instrument breaks it into brittle fibrous bits, easily crushed between the fingers to a yellow-brown, snuff-like powder. The timber has by this time lost its coherence, which, as we have seen, depends on the firm interlocking and holding together of the uninjured fibrous elements, and may give way under even light loads—a fact only too well known to builders and tenants. The walls of the wood elements (tracheides, vessels, fibers, or cells, according to the kind of timber, and the part affected) are now, in fact, reduced more or less to powder, and if such badly diseased timber is placed in water, it rapidly absorbs it and sinks; the wood in this condition also readily condenses and absorbs moisture from damp air—a fact which we shall see has an important bearing on the progress of the disease itself.

If such a piece of badly diseased deal as I have shortly described is carefully examined, the observer is easily convinced that fungus filaments (mycelium) are present in the timber, and the microscope shows that the finer filaments of the mycelium (hyphæ) are permeating the rotting timber in all directions—running between and in the wood elements, and also on the surface, much as in the case shown in Fig. 17. In a vast number of cases, longer or shorter, broader or narrower, cords of grayish-white mycelium may be seen coursing on the surface and in the cracks; in course of time there will be observed flat cake-like masses of this mycelium, the hyphæ being woven into felt-like sheets, and these may be extending themselves on to neighboring pieces of timber, or even on the brick-work or ground on which the timber is resting. These cord-like strands and cake-like masses of felt, with their innumerable fine filamentous continuations in the wood, constitute the vegetative body or mycelium of a fungus known as *Merulius lacrymans.* Under certain circumstances, often realized in cellars and houses, the cakes of mycelium are observed to develop the fructification of the fungus, illustrated in Fig. 18.

To understand the structure of this fructification we may contrast it with that of the *Polyporus* or *Trametes* referred to in the last article; where in the latter we find a number of pores leading each into a tubular cavity lined with the cells which produce the spores, the *Merulius* shows a number of shallow depressions lined by the sporogenous cells. The ridges which separate these depressed areolæ have a more or less zigzag course, running together, and sometimes the whole presents a likeness to honeycomb; if the ridges were higher, and regularly walled in the depressed areas, the structure would correspond to that of a *Polyporus* in essential points. The spores are produced in enormous numbers on this areolated surface, which is directed downward, and is usually golden-brown, but may be dull in color, and presents the remarkable phenomenon of exuding drops of clear water, like tears, whence the name *lacrymans.* In well grown specimens, such as may sometimes be observed on the roof of a cellar, these crystal-like tears hang from the areolated surface like pendants, and give an extraordinarily beautiful appearance to the whole; the substance of the glistening *Merulius* may then be like shot-velvet gleaming with bright tints of yellow, orange, and even purple.

It has now been demonstrated by actual experiment that the spores of the fungus *Merulius lacrymans* will germinate on the surface of damp timber, and send their germinal filaments into the tracheides, boring through the cell walls, and extending rapidly in all directions. The fungus mycelium, as it gains in strength by feeding upon the substance of these cell walls, destroys the wood by a process very similar to that already described (compare Fig. 14, Article III.).

It appears, however, from the investigations of Poleck and Hartig, that certain conditions are absolutely necessary for the development of the mycelium and its spread in the timber, and there can be no question that the intelligent application of the knowledge furnished by the scientific elucidation of the biology of the fungus is the key to successful treatment of the disease. This is, of course, true of all the diseases of timber, so far as they can be dealt with at all, but it comes out so distinctly in the present case that it will be well to examine a little at length some of the chief conclusions.

Merulius, like all fungi, consists of relatively large quantities of water—50 to 60 per cent. of its weight at least—together with much smaller quantities of nitrogenous and fatty substances and cellulose, and minute but absolutely essential traces of mineral matters, the chief of which are potassium and phosphorus. It is not necessary to dwell at length on the exact quantities of these matters found by analysis, nor to mention a few other bodies of which traces exist in such fungi. The point just now is that all these materials are formed by the fungus at the expense of the substance of the wood, and for a long time there was considerable difficulty in understanding how this could come about.

The first difficulty was that although the "dry rot fungus" could always be found, and the mycelium was easily transferred from a piece of diseased wood to a piece of healthy wood, provided they were in a suitable warm, damp, still atmosphere, no one had as yet succeeded in causing the spores of the *Merulius* to germinate, or in following the earliest stages of the disease. Up to about the end of the year 1884 it was known that the spores refused to germinate either in water or in decoctions of fruit; and repeated trials were made, but in vain, to see them actually germinate on damp wood, until two observers, Poleck and Hartig, discovered about the same time the necessary conditions for germination. It should be noted here that this difficulty in persuading spores to germinate is by no means an isolated instance: we are still ignorant of the conditions necessary for the germination of the spores of many fungi—*e. g.* the spores of the mushroom, according to De Bary; and it is known that in numerous cases spores need very peculiar treatment before they will germinate. The peculiarity in the case of the spores of *Merulius lacrymans* was found by Hartig to be the necessity of the presence of an alkali, such as ammonia; and it is found that in cellars, stables, and other outhouses where ammoniacal or alkaline emanations from the soil or elsewhere can reach the timber, there is a particularly favorable circumstance afforded for the germination of the spores. The other conditions are provided by a warm, still, damp atmosphere, such as exists in badly ventilated cellars, and corners, and beneath the flooring of many buildings.

Careful experiments have shown beyond all question that the "dry rot fungus" is no exception to other fungi with respect to moisture: thoroughly dry timber, so long as it is kept thoroughly dry, is proof against the disease we are considering. Nay, more, the fungus is peculiarly susceptible to drought, and the mycelial threads and even the young fructifications growing on the surface of a beam of timber in a damp, close situation may be readily killed in a day or two by letting in thoroughly dry air: of course, the mycelium deeper down in the wood is not so easily and quickly destroyed, since not only is it more protected, but the mycelial strands are able to transport moisture from a distance. Much misunderstanding prevails as to the meaning of "dry air" and "dry wood:" as a matter of fact, the air usually contains much moisture, especially in cellars and quiet corners devoid of draughts, such as *Merulius* delights in, and we have already seen how dry timber rapidly absorbs moisture from such air. Moreover, the strands of mycelium may extend into damp soil, foundations, brickwork, etc.; in such cases they convey moisture to parts growing in apparently dry situations.

A large series of comparative experiments, made especially by Hartig, have fully established the correctness of the conclusion that damp foundations, walls, etc., encourage the spread of dry rot, quite independently of the quality of the timber. This is important, because it has long been supposed that timber felled in summer was more prone to dry rot than timber felled in winter: such, however, is not shown to be the case, for under the same conditions both summer and winter wood suffer alike, and decrease in weight to the same extent during the progress of the disease. There is an excellent opportunity for further research here, however, since one observer maintains that in one case at any rate (*Pinus sylcestris*) the timber felled at the end of April suffered from the disease, whereas that felled in winter resisted the attacks of the fungus: internal evidence in the published account supports the suspicion that some error occurred here. The wood which succumbed was found to contain much larger quantities of potassium and phosphorus (two important ingredients for the fungus), and Poleck suggests that this difference in chemical constitution explains the ease with which his April specimens were infected.

It appears probable from later researches and criticism that Poleck did not choose the same parts of the two stems selected for his experiments, for (in the case of *Pinus sylvestris*) the heart wood is attacked much less energetically than the sap wood—a circumstance which certainly may explain the questionable results if the chemist paid no attention to it, but analyzed the sap wood of one and the heart wood of the other piece of timber, as he seems to have done.

The best knowledge to hand seems to be that no difference is observable in the susceptibility to dry rot of winter wood and summer wood of the same timber, *i. e. Merulius lacrymans* will attack both equally, if other conditions are the same.

But air dry and thoroughly seasoned timber is much less easily attacked than damp, fresh cut wood of the same kind, both being exposed to the same conditions.

Moreover, different timbers are attacked and destroyed in different degrees. The heart wood of the pine is more resistant than any spruce timber. Experimental observations are wanted on the comparative resistance of oak, beech, and other timbers, and indeed the whole question is well worth further investigation.

When the spore has germinated, and the fungus hyphæ have begun to grow and branch in the moist timber, they proceed at once to destroy and feed upon the contents of the medullary rays; the cells composing these contain starch and saccharine matters, nitrogenous substances, and inorganic elements, such as potassium, phosphorus, calcium, etc. Unless there is any very new and young wood present, this is the only considerable source of proteid substances that the fungus has: no doubt a little may be obtained from the resin passages, but only the younger ones. In accordance with this a curious fact was discovered by Hartig: the older parts of the hyphæ pass their protoplasmic contents on to the younger growing portions, and so economize the nitrogenous substances. Other food substances are not so sparse; the lignified walls inclose water and air, and contain mineral salts, and such organic substances as coniferin, tannin, etc., and some of these are absorbed and employed by the fungus. Coniferin especially appears to be destroyed by the hyphæ.

The structure of the walls of the tracheides and cells of the wood is completely destroyed, as the fungus hyphæ extract the minerals, cellulose, and other sub-

* Continued from SUPPLEMENT, No. 643, p. 10278.

stances from them. The minerals are absorbed at points of contact between the hyphæ and the walls, reminding us of the action of roots on a marble plate: the coniferin and other organic substances are no doubt first rendered soluble by a ferment, and then absorbed by the hyphæ. This excretion of ferment has nothing to do with the excretion of water in the liquid state, which gives the fungus its specific name. The "tears" themselves have no solvent action on wood.

It will be evident from what has been stated that the practical application of botanical knowledge is here not only possible, but much easier than is the case in dealing with many other diseases.

It must first be borne in mind that this fungus spreads, like so many others, by means of both spores

FIG. 17.—Portion of the mycelium of *Merulius lacrymans* removed from the surface of a beam of wood. This cake-like mass spreads over the surface of the timber, to which it is intimately attached by hyphæ running in the wood substance. Subsequently it develops the spore-bearing areolæ near its edges. The shading indicates differences in color, as well as irregularities of surface.

and mycelium: it is easy to see strands of mycelium passing from badly diseased planks or beams, etc., across intervening brickwork or soil, and on to sound timber, which it then infects. The spores are developed in countless myriads from the fructifications described, and they are extremely minute and light. It has been proved that they can be carried from house to house on the clothes and tools, etc., of workmen, who in their ignorance of the facts are perfectly careless about laying their coats, implements, etc., on piles of the diseased timber intended for removal. Again, in replacing beams, etc., attacked with dry rot, with sound timber, the utmost ignorance and carelessness are shown: broken pieces of the diseased timber are left about, whether with spores on or not; and I have myself seen quite lately sound planks laid close upon and nailed to planks attacked with the "rot." Hartig proved that the spores can be carried from the wood of one building to that of another by means of the saws of workmen

But perhaps the most reckless of all practices is the usage of partially diseased timber for other constructive purposes, and stacking it meanwhile in a yard or outbuilding in the neighborhood of fresh cut unseasoned timber. It is obvious that the diseased timber should be removed as quickly as possible, and burnt at once; if used as firewood in the ordinary way, it is at the risk of those concerned. Of course the great danger consists in the presence of many ripe spores, and their being scattered on timber which is under proper conditions for their germination and the spread of the mycelium.

It is clearly an act approaching those of a madman

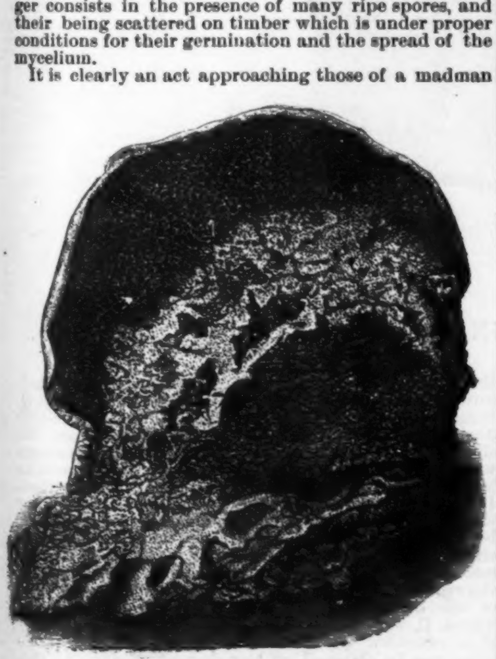


FIG. 18.—Mature fructification of *Merulius lacrymans*. The cake-like mass of felted mycelium has developed a series of areolæ (in the upper part of the figure), on the walls of which the spores are produced. In the natural position this spore-bearing layer is turned downward, and in a moist environment pellucid drops or "tears" distill from it. The barren part in the foreground was on a wall, and the remainder on the lower side of a beam; the fungus was photographed in this position to show the structure.

to use fresh "green" timber for building purposes; but it seems certain that much improperly dried and by no means "seasoned" timber is employed in some modern houses. Such wood is peculiarly exposed to the attacks of any spores or mycelium that may be near.

But even when the beams, door posts, window sashes, etc., in a house are made of properly dried and seasoned deal, the danger is not averted if they are supported on damp walls or floors. For the sake of illustration I will take an extreme case, though I have no doubt it has been realized at various times. Beams of thoroughly seasoned deal are cut with a saw which has previously been used for cutting up diseased timber, and a few spores of *Merulius* are rubbed off from the saw, and left sticking to one end of the cut beam; this end is then laid on or in a brick wall or foundation which has only stood long enough to partially dry. If there is no current of dry air established through this part, nothing is more probable than that the spores will germinate, and the mycelium spread, and in the course of time—it may be months afterward—a mysterious outbreak of dry rot ensues. There can be no question that the ends of beams in new houses are peculiarly exposed to the attacks of dry rot in this way.

The great safeguard—beyond taking care that no spores or mycelium are present from the first—is to arrange that all the brickwork, floors, etc., be thoroughly dry before the timber is put in contact with them: or to interpose some impervious substance—a less trustworthy method. Then it is necessary to aerate and ventilate the timber; for *dry* timber *kept dry* is proof against "dry rot."

The ventilation must be real and thorough, however, for it has been by no means an uncommon experience to find window sashes, door posts, etc., in damp buildings, with the insides scooped out by dry rot, and the aerated outer shells of the timber quite sound; this is undoubtedly often due to the paint on the outer surfaces preventing a thorough drying of the deeper parts of the wood.

Of course the question arises, and is loudly urged, is there no medium which will act as an antiseptic, and kill the mycelium in the timber in the earlier stages of the disease? The answer is, that mineral poisons will at once kill the mycelium on contact, and that creosote, etc., will do the same; but who will take the trouble to thoroughly impregnate timber in buildings such as harbor dry rot? And it is simply useless to merely paint these specifics on the surface of the timber: they soak in a little way, and kill the mycelium on the outside, but that is all, and the deadly rot goes on destroying the inner parts of the timber just as surely.

There is one practical suggestion in this connection, however: in cases where properly seasoned timber is used, the beams laid in the brick walls might have their ends creosoted, and if thoroughly done this would probably be efficacious during the dangerous period while the walls finished drying. I believe this idea has been carried out lately by Prof. Hartig, who told me of it. The same observer was also kind enough to show me some of his experiments with dry rot and antiseptics: he dug up and examined in my presence glass jars containing each two pieces of deal—one piece sound and the other diseased. The sound pieces had been treated with various antiseptics, and then tied face to face with the diseased pieces, and buried in the jar for many months or even two years.

However, I must now leave this part of the subject, referring the reader to Hartig's classical publications for further information, and pass on to a sketch of what is known of other kinds of "dry rot." It is a remarkable fact, and well known, that *Merulius lacrymans* is a domestic fungus, peculiar to dwelling houses and other buildings, and not found in the forest. We may avoid the discussion as to whether or no it has ever been found wild: the one case, it is true, is on record on good authority, but the striking peculiarity about it is that, like some other organisms, this fungus has become intimately associated with mankind and human dwellings, etc.

The case is very different with the next disease-producing fungus I propose to consider. It frequently happens that timber which has been stacked for some time in the wood yards shows red or brown streaks, where the substance of the timber is softer, and in fact may be "rotten;" after passing through the saw mill these streaks of bad wood seriously impair the value of the planks, beams, etc., cut from the logs.

Prof. Hartig, who has devoted much time to the investigation of the various forms of "dry rot," informs me that this particular kind of red or brown streaking is due to the ravages of *Polyporus vaporarius*. The mycelium of this fungus destroys the structure of the wood in a manner so similar to that of the *Merulius* that the sawyers and others do not readily distinguish between the two. The mycelium of *Polyporus vaporarius* forms thick ribbons and strands, but they are snowy white, and not gray like those of *Merulius lacrymans*: the structure, etc., of the fructification are also different. I have shown in Fig. 19 a piece of wood undergoing destruction from the action of the mycelium of this *Polyporus*, and it will be seen how the diseased timber cracks just as under the influence of *Merulius*.

Now *Polyporus vaporarius* is common in the forests, and Hartig has found that its spores may lodge in cracks in the barked logs of timber lying on the ground —cracks such as those in Fig. 1 (see p. 10172). In the particular forests of which the following story is told, the felling is accomplished in May (because the trunks can then be readily barked, and also because such work cannot be carried on there in the winter), and the logs remain exposed to the sun and rain, and vicissitudes of weather generally, for some time. Now it is easy to see that rain may easily wash spores into such cracks as those referred to, and the fungus obtains its hold of the timber in this way.

The next stage is sending the timber down to the timber yards, and this is accomplished, in the districts referred to, by floating the logs down the river. Once in the river, the wood swells, and the cracks close up; but the fungus spores are already deeply imprisoned in the cracks, and have no doubt by this time emitted their germinal hyphæ, and commenced to form the mycelium. This may or may not be the case; the important point is simply that the fungus is already there. Having arrived at the timber wharves, the logs are stacked for sawing in heaps as big as houses; after a time the sawing up begins. It usually happens that the uppermost logs when cut up show little or no signs of rot; lower down, however, red and brown streaks appear in the planks, and when the lowermost logs are reached, perhaps after some weeks or months, deep channels of powdery, rotten wood are found, running up inside the logs in such a way that their transverse sections often form triangles or V shaped figures, with the apex of the triangle or V turned toward the periphery of the log.

The explanation is simple. The uppermost logs on the stack have dried sufficiently to arrest the progress of the mycelium, and therefore of the disease; the lower logs, however, kept damp and warm by those above, have offered every chance to the formation and spread of the mycelium deep down in the cracks of the timber. I was much impressed with this ingenious explanation, given to me personally by Prof. Hartig, and illustrated by actual specimens. It will be noticed how fully it explains the curious shape of the rotten

FIG. 19.—A piece of pine wood attacked by the mycelium of *Polyporus vaporarius*. The timber has warped and cracked under the action of the fungus, becoming of a warm brown color at the same time; in the crevices the white strands of felt-like mycelium have then increased, and on splitting the diseased timber they are found creeping and applying themselves to all the surfaces. Except that the color is snowy white, instead of gray, this mycelium may easily be mistaken for that of *Merulius*. The fructification which it develops is, however, very different. (After R. Hartig.)

courses, because the depths of the cracks are first diseased, and the mycelium spreads thence.

Obviously some protection would be afforded if the bark could be retained on the felled logs, or if they could be at once covered and kept covered after barking; and, again, something toward protection might be done by carting instead of floating the timber, when possible. At the same time, this is not a reliable mode of avoiding the disease by itself; and even the dry top logs in the saw yard are not safe. Suppose the following case. The top logs of the stack are quite dry, and are cut into beams and used in building; but they have spores or young mycelium trapped in the cracks at various places. If, from contact with damp brickwork or other sources of moisture, these spores or mycelia are enabled to spread subsequently, we may have "dry rot" in the building; but this "dry rot" is due to *Polyporus vaporarius*, and not to the well known *Merulius lacrymans*.

There can probably be no question of the advantage of creosoting the ends of such rafters, beams, etc.; since the creosote will act long enough to enable the timber to dry, if it is ever to dry at all. But the mycelium of *Polyporus vaporarius* makes its way into the still standing timber of pines and firs; for it is a wound parasite, and its mycelium can obtain a hold at places which have been injured by the bites of animals, etc.; it thus happens that this form of "dry rot" is an extremely dangerous and insidious one, and I have little doubt that it costs our English timber merchants something, as well as Continental ones. Nor are the above the only kinds of "dry rot" we know. Hartig has described a disease of pine wood caused by *Polyporus mollis*, which is very similar to the last in many respects, and the suspicion may well gain ground that this important subject has by no means been exhausted yet.

THE orange tree was introduced to Jamaica more than a hundred years ago. It is now found practically wild over the settled parts of the island, and the fruit is exported to the value of nearly £50,000 per annum. Up to quite recently very few trees were planted. Nearly the whole were sown by the agency of frugivorous birds, who carried the seeds from place to place and dropped them in native gardens, coffee plantations, sugar estates, and grass lands.—*D. Morris.*

THE SIMONDS METAL ROLLING MACHINE.

THE aim at economy and rapidity of manufacture, together with the utmost attainable accuracy of work, has during the past few years been responsible for a remarkable degree of mechanical progress. Particularly noticeable, perhaps, has this development been in connection with machinery for the working of metals; new ideas and new designs having crowded one another in rapid succession. As an example of probably the most recent departure in this line, and one of far-reaching importance, the metal rolling machines of the Simonds Rolling Machine Company, of Boston, whose works are at Fitchburg, Mass., are of interest, and we take pleasure, therefore, in presenting in this issue engravings which very clearly illustrate the design and manner of working of one of them. The drawings and photographs from which these were made were kindly furnished us by Mr. George F. Simonds, the president of the company and inventor of the machine; and the performance of the plant itself, which embraces thirteen of the machines, we were offered an opportunity to witness during a recent visit to Fitchburg.

The engraving on this page will impart a fair idea of the general characteristics of the machine, though for the details our readers must refer to the engravings on the succeeding pages, representing a plan, and side and end elevations and section, together with different views of one form of die used, and a specimen of work done by the machine. We will here explain at once that the latter is designed, as may already have been inferred, for rolling accurately and in a short space of time a large variety of work which at present is turned out by more laborious and expensive processes, such as lathe turning, the customary methods of forging, and others. The machine, it will be noticed, consists in the main of a substantial bed and two standards, M M, which are practically duplicated within and below the frame and floor line, as shown in Fig. 2. Mounted on these standards, by means of suitable fixtures, are a number of rollers, *r*, in the manner illustrated in Figs. 1, 2, 3, and 4, arranged to act as front, rear, and side supports and guides to cast iron traveling platens, O O. They thus take the place of the ordinary sliding surfaces, and, affording only rolling contact, reduce friction. The reference letters on the platens, O, unfortunately have the appearance of holes, but we trust that this will lead to no misunderstanding. Fitted into the backs of these platens are two racks (see Figs. 1, 3, and 4), gearing with pinions, B, Fig. 3, in the interior, mounted on the shafts, A A, and indicated only by dotted lines in Fig. 2. These pinions have power transmitted to them from the driving pulleys, P and P', through a series of gear wheels, *a*, *b*, *c*, *d*, *e*, *f*, *g*, and *h*, shown in the plan and also indicated in the elevation, Fig. 2. The pulleys, P and P', run in opposite directions, one of them having an open and the other a crossed belt, and both are mounted loosely on the shaft, R, to which is attached the friction clutch pulley, Q. From Figs. 2 and 3 it will be readily understood that as the lever, F, is moved either from or toward the machine, the shaft, G, to which it is fastened by a set screw, is turned, and by means of the small crank at the left transmits motion to the transverse rod, H, and from this to the collar, J, and pulley, Q, by a short vertical pivoted lever at the back of the machine. By means of this arrangement the pulley, Q, can be shifted either to the right or to the left, engaging with the pulley, P' or P, as illustrated in Fig. 3, and thus imparting motion in either direction desired to the shaft, R, and pinion, *a*. From the latter the motion is transmitted further, as we have already explained, the pinions on the shafts, A A, in all cases turning in opposite directions, so that one of the platens fitted with the central racks always travels upward while the other travels downward. The gear wheel, *g*, shown in Figs. 3 and 4, is supported by a frame, of which the arrangement will be understood from the different engravings.

Returning to the platens, O O, it will be observed in Figs. 2 and 4 that they carry the cast iron plates, N N, into which the dies proper are dovetailed, the section of these for this purpose being as shown in Fig. 5. The die there illustrated is for forging car axles, of one of which a sketch is also given. From what we have already said it will be understood that the dies are used in pairs, moved in opposite directions over the metal to be shaped, the die surfaces, of course, being exactly alike. The die illustrated affords a good example of the method of construction adopted. From the plane faces of the dies, which lie parallel to each other when in position for work, rise the forming and reducing and spreading surfaces, the plane portions serving to support and steady the work and prevent it from rocking. The reducing surfaces are grooved or serrated in order to insure a firm grip on the hot and plastic metal and perfect regularity in its rotation, and being thus arranged obliquely, the marks made in the metal by the serrations are obliterated in subsequent revolutions of the blank, and the rate of the surface movement of the latter, where work is being performed, is the same as the rate of linear movement of the dies. The reducing faces commence to work on the metal at the extreme left, where they meet in a point, and when the hot blank is placed between the dies, the central reduction of the axle is commenced by the narrow end of the tapering raised portion, *a*, of the die face. It will be noticed from the cross section of the die that, in general configuration, the raised portions are like the half section of the axle, the shearing off squarely of the ends of the axle being accomplished by the level edge cutters, *e c*. The edges of these cutter projections are also serrated, so that the rotation of the blank is under control throughout the length of travel of the die. The material operated upon, we need perhaps not specially explain, is compressed and condensed as it assumes the required shape under the dies. The construction and function of all other forms of dies for use in the machine are on the same general basis.

The blank to be operated upon is inserted between the dies, and rests on the supporting plate marked V, in Figs. 2 and 4, one of the dies being at or near the end of its up stroke, and the other at or near the end of its down stroke, so that the extreme ends of the gripping surfaces of the dies are opposite each other in a line passing through the centers of the shafts, A A. The rest, V, is adjustable vertically, and its position is dependent upon the size of the blank, being such that the center line of the blank is also in the same horizontal plane with the center line of the shafts, A A. The friction pulley, Q (Figs. 3 and 4), being then thrown into gear with either pulley, P or P', as the case may require, by the means already described, causes one of the die platens to travel up and the other down, until the extremities of the cutting-off edges, *c c* (Fig. 5), are opposite each other, when a finished car axle, or whatever other product the dies may have been designed for, is the result. The whole operation occupies only the fraction of a minute, a fact strikingly suggestive of the rapidity with which work can be turned out. The smaller the article made, the greater may of course be the speed of working, boot calks for lumbermen, for example, now being turned out at the works of the Simonds Rolling Machine Company at the rate of from 10,000 to 20,000 per day. For different sizes of stock the distance between the die faces can be adjusted by means of the hand wheel, K (Figs. 2 and 3), carrying on its shaft a small spur wheel which gears with two larger spur wheels, as shown in Fig. 4. These wheels in turn are attached to two screws, S, Fig. 2, by means of which the right hand standard, M, with its lower extension, can be moved either nearer to or further away from the standard at the left, which is immovable. By means of a pointer and suitable graduations for the hand wheel, K, the distance between the die faces may be adjusted to within small fractions of an inch. The desired adjustment having been made, the standard is rigidly clamped to the frame of the machine by the bolts passing through the side flanges. The die platens, after having performed the strokes just considered, are brought back to their initial positions by reversing the motion, the pulley, Q, being thrown into gear with the belt pulley, which during that time has been running loosely on the shaft, R, Fig. 4. A careful study of the engravings will explain our meaning more clearly. The machine is then ready to repeat the operation just described. It will be noted that the reversal of motion, as we have thus far described it, is accomplished by means of the lever, F, within easy reach of the attendant. The machine may, however, be made to accomplish this automatically by means of the two gear wheels, C and D, shown in Fig. 2, the latter wheel being fast on one of the driving pinion shafts, A. The body of the wheel, C, with which it meshes and which is driven by it, is provided with a circular T slot, in which two stops can be clamped at any desired points. In this slot also is a loose pin fitted to the upper end of the lever, E, which is secured to the shaft, G, operating the mechanism of the friction pulley, Q, by an intermediate crank. The wheel, C, obviously can revolve without affecting the position of the rod, E, in any way until the upper horizontal projection of the latter is struck by either one of the stops mentioned. This being the case, the lever is either raised or depressed according to the direction of revolution of the wheel, C, given to it by the wheel, D, the rod, G, is turned in either one direction or the other, and, through its attachments, one disengages the clutch pulley, Q, from the pulley, P, and throws it into gear with the pulley, P', or *vice versa*, in either case reversing the motion of the shaft, R, and of the die platens, O O. The length of stroke traveled through by these before reversal is

FIG. 1.—GENERAL VIEW.

THE SIMONDS METAL ROLLING MACHINE

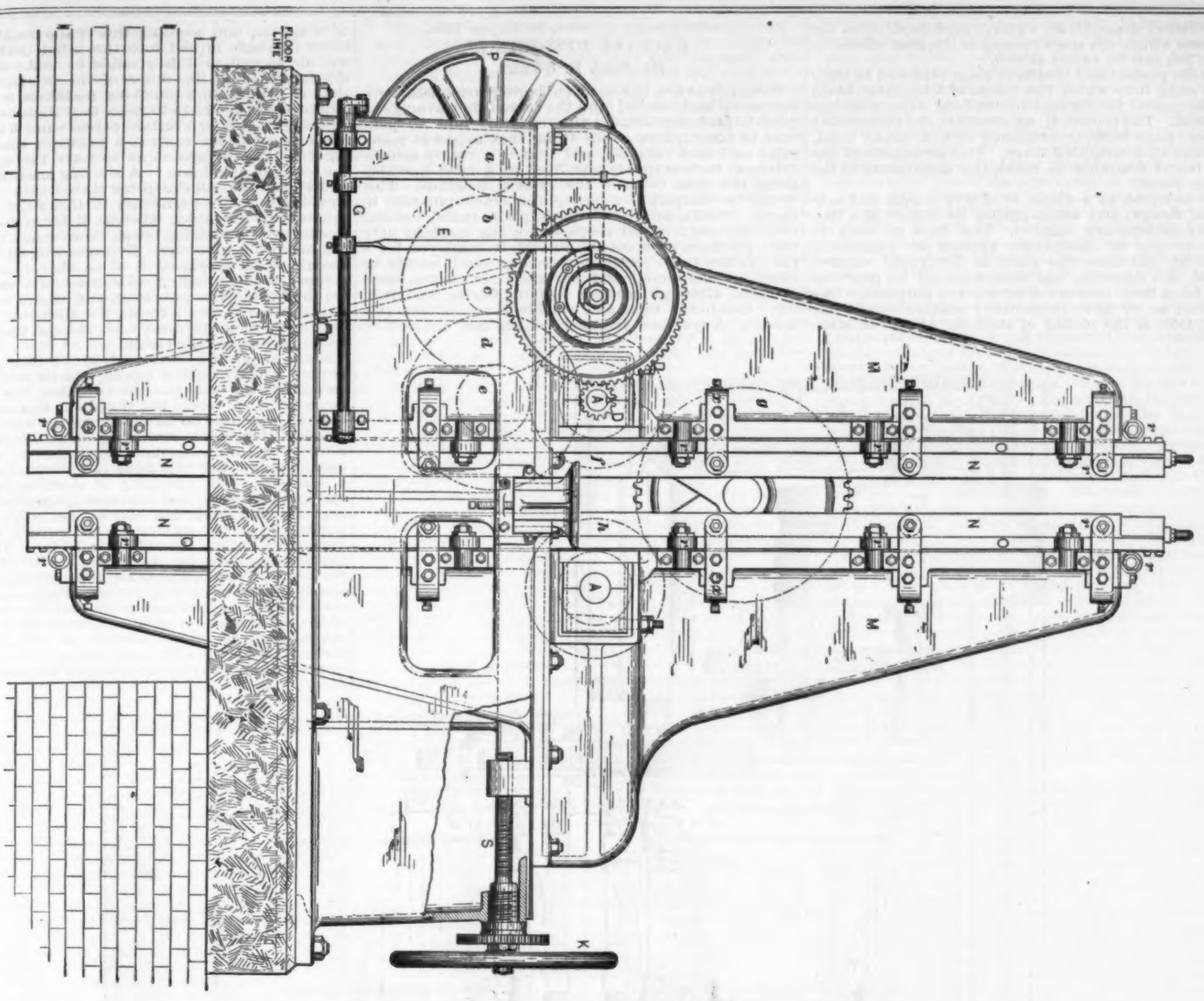


FIG. 2.—SIDE ELEVATION.

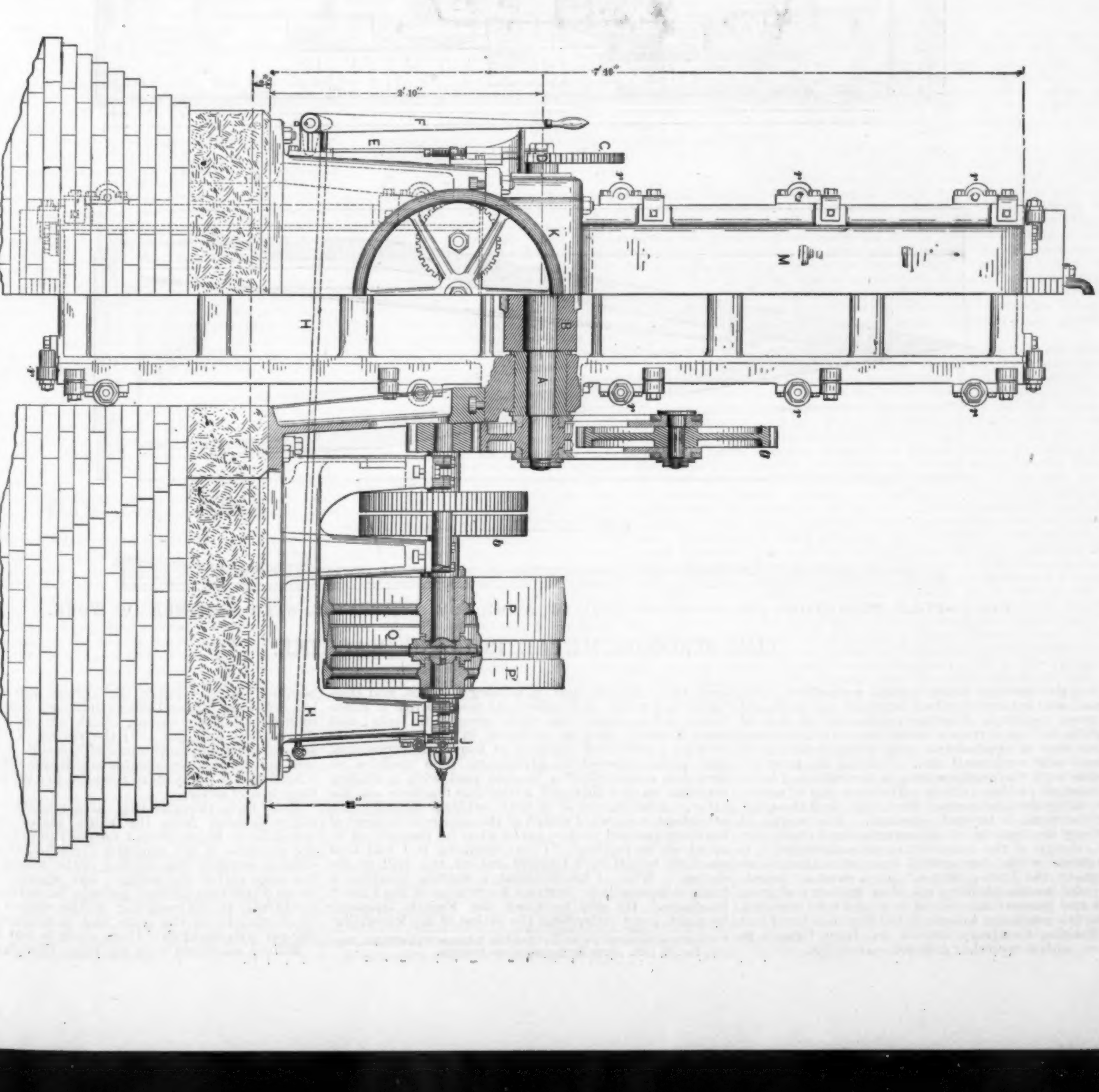


FIG. 3.—END VIEW AND VERTICAL SECTION.

THE SIMONDS METAL ROLLING MACHINE.

thus effected depends, as we have explained, upon the positions which the stops occupy in the gear wheel, C, and which can be varied at will.

The die platens and dies have rings attached to their upper ends, into which the hooks of a hoisting tackle may be passed for convenient removal when a change is desired. The pulley, Q, as shown in the perspective view on page 10282, is furnished with a brake band, held taut by a weighted lever. This arrangement has been found desirable to check the momentum of the moving parts.

The machine, as a whole, is of very simple and substantial design, and accomplishes its object in a thoroughly satisfactory manner. The lines of work to which it may be successfully applied are practically unlimited, and since the plant at Fitchburg was first started, Mr. Simonds has demonstrated its practical value for a large number of interesting purposes. One of these, as we have incidentally pointed out in our description, is the rolling of steel car axles. In addition, full size carriage axles, conical projectiles, spindles, and also spheres for ball bearings are produced with great rapidity. Another production is that of steel calks for lumbermen's boots, the work thus ranging from that of appreciable proportions to articles of comparatively very small size. Perhaps the most remarkable work the machine does is the rolling of bolts and screws of endless variety. The economy of manufacture is for obvious reasons very great, and the quality of the work is beyond reproach. The works at Fitchburg are mainly of an experimental character, and the design of the company, as we understand it, is to establish works for special lines of manufacture throughout the United States. At present all indications point to the building up of an industry of great extent and general interest to iron and steel workers. An English company, known as the Simonds Steel and Iron Forging Company, limited, has been formed in London, with a capital of £150,000.—*Iron Age.*

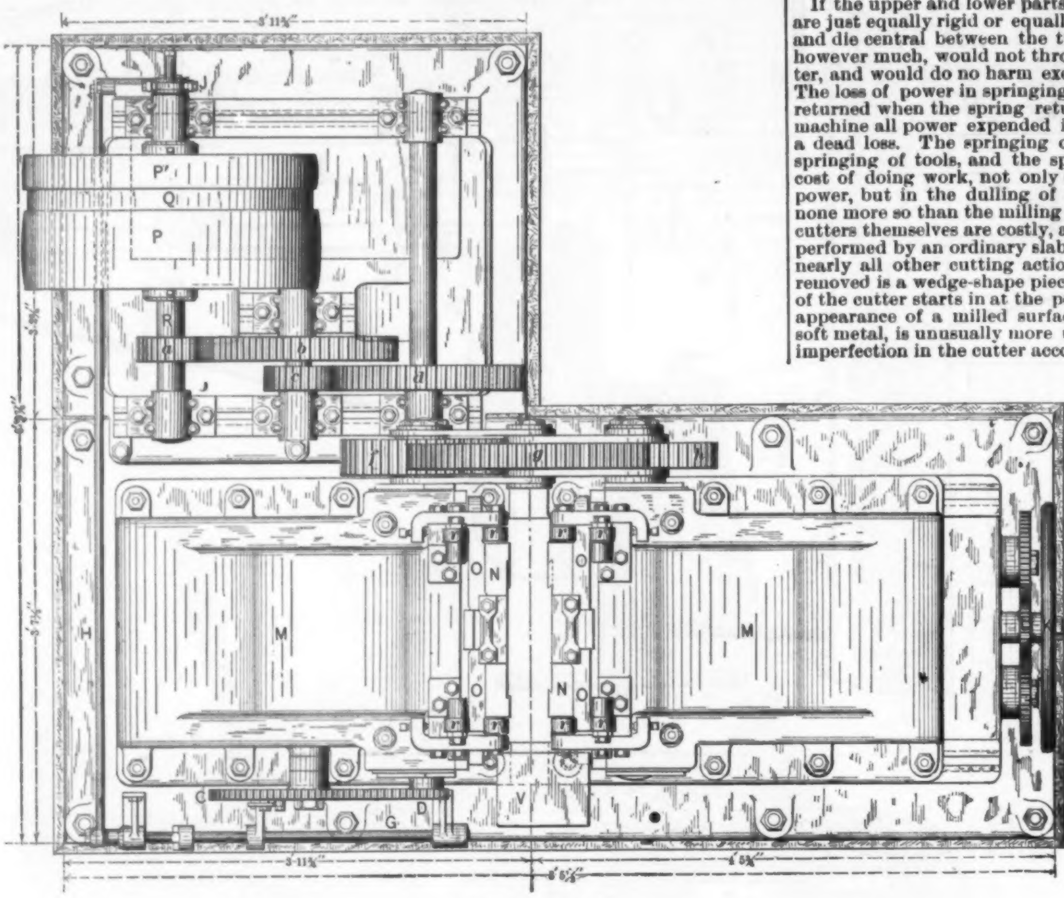


FIG. 4.—PLAN.

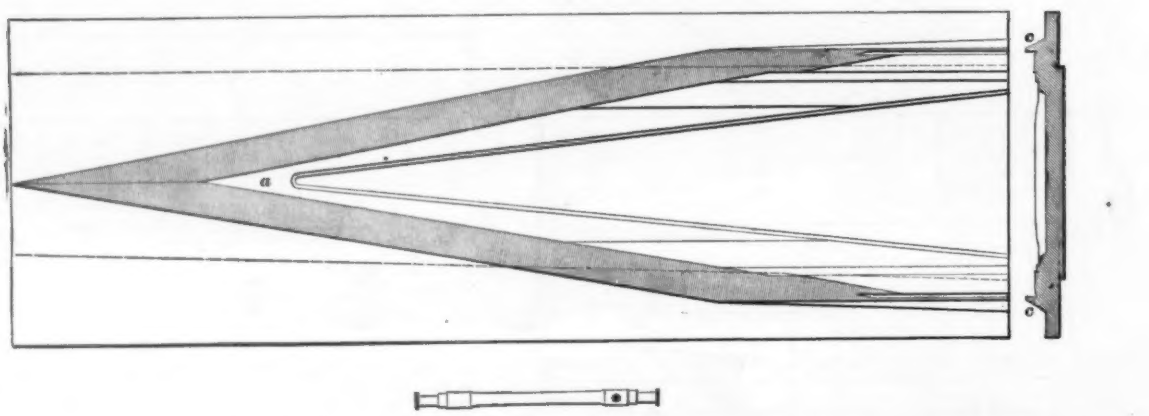


FIG. 5.—PLAN, ELEVATION, AND CROSS SECTION OF A DIE FOR A CAR AXLE, WITH SPECIMEN OF WORK.

THE SIMONDS METAL ROLLING MACHINE.

[Continued from SUPPLEMENT, No. 643, page 10269.]

MACHINE DESIGNING.*

By JOHN E. SWEET.

PERFECT as are the modern boring machines, both horizontal and vertical (and the reason they average so good is probably because the imitators find no poor ones to copy), there is one thing that might in many cases be found valuable, and that is a rotary spindle driven at various speeds and fixed in a head movable along the cross beam of the vertical machine. This would be complete for boring the crank pin hole in engine cranks, and a complete plain radial drilling machine, useful in all shops where the machine only has legitimate work enough to keep it employed for a part of the time. Such a machine could hardly be called a compound, and certainly not a combined machine, although used for turning, boring, and drilling. Combined tools and machines are seldom successful. A common hammer, which may be said to have two business ends, a lathing hatchet, and Disston's nigger saw, as I believe we used to call it down South, cover nearly the whole ground in tools; and Scott Russell's idea, as expressed in his remark, after viewing a combined machine at the Paris exposition, may be remembered to advantage. The machine referred to consisted of a central post with a drilling machine on one side and a slotting machine on the other. After staring at it with evident curiosity, the attendant, somewhat elated at the apparent interest of his distinguished visitor, asked what he thought of it, to which he replied: "I was thinking if I had that machine which part I would cut off, the drill or the slotter." What I know about a slotting machine is fairly comparable to Burton's knowledge of the French language. He said he knew the French language by sight, and that's about the extent of my knowledge of a slotter, and possibly this is the reason I could never persuade myself into the belief that they look well or as well as it is possible to make them. The slotting machine, like others of the overhanging class, that is, drilling and punching machines, is subject to strains that they have to resist to a disadvantage, and where springing to a certain extent cannot be avoided. Might it not be set down as a principle that the framing should be devised so as to have the springing do the least possible harm? A slotting machine might be so designed that all the spring there was in the machine would have a direct tendency to throw the cut out of square with the table; whereas, if the sliding bar was worked with a walking beam, there would be no detrimental spring whatever. Evil resulting in a punching machine from springing is of another character altogether; much springing adds immensely to the power required to do the punching, and unless specially designed to avoid such a result, the springing throws the punch out of adjustment with the die, and bad work and dull tools are the result.

If the upper and lower parts of a punching machine are just equally rigid or equally elastic, and the punch and die central between the two, then the springing, however much, would not throw the tools out of register, and would do no harm except the waste of power. The loss of power in springing a machine is sometimes returned when the spring returns, but in a punching machine all power expended in springing the frame is a dead loss. The springing of machine framing, the springing of tools, and the springing, all add to the cost of doing work, not only on account of a loss of power, but in the dulling of the cutters, and in this none more so than the milling machine. The tools or cutters themselves are costly, and the act of cutting, as performed by an ordinary slabbing cutter, differs from nearly all other cutting action. Each separate chip removed is a wedge-shape piece, and the cutting edge of the cutter starts in at the point of the wedge. The appearance of a milled surface, as ordinarily left on soft metal, is unusually more uneven than any feed or imperfection in the cutter accounts for, and it is safe to assume that the teeth of the cutters slip over more or less and then bite and gouge in deeper than if each one took its allotted amount. Both actions tend to dull the cutters, and not only the spring of the machine and cutters tends to produce this result, but an elastic feed motion also contributes to this same result, so that a rigid feed is likely more essential in a milling machine than in any other.

Many have thought that as a remedy for the difficulties arising from the cause above described, it would be an improvement to feed the work to the milling machine in the opposite direction, that is, so the cutting edges of the milling cutter would start in at the large end of the wedge; but whether this would be an advantage (except, perhaps, in cutting shapes) is doubtful. In the roughing cut the cutting edge would be starting in on the scale, and in finishing flat work the cut is so slight that there could be but little gain.

Milling machines were for years thought to be well

* A lecture delivered before the Franklin Institute, Philadelphia, Monday, Jan. 30, 1888. From the journal of the Institute.

adapted for small work, but not for large, and this idea is likely entertained by many yet, while others believe that the reason it has not proved successful in large work was because there were no large machines, while the truth probably is that the kind of work has more to do with the question of adaptability than the size, and that certain classes of work of whatever size can best be done by rotary cutters, while other kinds will always be best done by the planing, shaping, and slotting machines.

What cutting action shall be adopted to perform a certain operation is as much a question in machine designing as any other. The most perfect of all machine work is done by an emery or corundum wheel, and the next of all I have seen is done with what is usually understood, though perhaps not properly, an end mill. Cutting tools, traversing in curved paths across a flat surface, have an advantage in never following over twice in exactly the same path, as is the case in a planer tool, which probably accounts for the absence of chatter; but, on the other hand, the cutting blade traverses over eleven inches of distance to finish a seven-inch cut. The planer wastes time in stopping, running back, and starting, while the traversing blades are always at it.

After a half century of study over the lathe and planer, improvement still goes on, and in this view what may we not expect a quarter of a century hence of the milling and traversing cutters and emery cutting devices?

In all our planning and all our study there is one vital principle that is hardly ever thought of and never mentioned. We all look for the best new machine, but who to see which is to be the best old one? The mathematicians tell us which is the most perfect gear, but all their calculations are based on a new one, and no thought given to the one half or three-fourths worn out. An engine cylinder needs no counter bore when new, but experience has shown the necessity for it when old; and short cross heads, working on long slides without overlapping at the ends, soon wear the slides concave and themselves rounding, with the result, two curved surfaces of unequal radius always growing worse. The slides I will speak of later on. The gear tooth needs an undercut at the root as much as the cylinder needs a counter bore. The epicycloidal may be the best form for a new gear, and the single arc odontograph for an old one.

With the exception of the J. Morton Poole grinding machine, nearly every machine tool depends for the accuracy of its work upon the accuracy of sliding surfaces. In the best work special methods are adopted to make them true, after which they are left to fate to keep them so. Who has ever deliberately undertaken to plan and build a planing machine that should maintain perfect truth during its entire existence? The planing machine has a short table working on a long bed, the milling machine a long table working on a short bed; the lathe a short rest on long slides, and the shaper a long slide in a short guide.

The tool builder would laugh at the engine builder who should run a cross head on guides not cut away so the cross head would overrun at the ends; and yet he makes the sliding block on the cross feed of his lathe six inches long working on a dovetail two feet long, sometimes running off at one end and never at the other. The sum of the two fitted surfaces is thirty inches. If divided equally, that is, a fifteen-inch sliding on a fifteen-inch dovetail, the two would remain true and be a good job as long as the lathe lasted. This is one of the places where for lathes of moderate size there is no excuse for anything but wearing surfaces of equal length. The designer who finds any difficulties in this that he cannot overcome has too little genius for the job. Equal length sliding surfaces can usually be employed in all the slides on milling machines, punching machines and many others, and wherever possible the use of any other arrangement is simply poor designing, to give it the mildest criticism possible. A short sliding block on a long guide invariably gets bad sooner or later, and refitting becomes necessary.

The sliding head of a shaper invariably made longer than its guide is an ever-present nuisance and one that can be abated. The requirements call for a slide to work at all sorts of stroke from an inch to a foot and at positions varying as much as a foot. As now made, much of the back end of the sliding arm does not get a hundredth part of the wear that the front end does, and often none at all. As a result, in many establishments the thing may be worked for a year at short stroke and in one place; then when the attempt is made to use it in a different position, it is so loose in one position and so tight in another as to be worse than useless. The remedy is easy. Make the two sliding surfaces of a length and attach the connecting rod to an immovable pin, then both ends of the slide will always overrun, whether the stroke is an inch or a foot. To provide for the varying position of cut, the plan shown in Fig. 3 is presented.

This slide is guided in the usual way and driven by a connecting rod rigidly attached to the side or bottom, as most convenient. Instead of the slides carrying a head and tool post, it is bored out, split, and provided with two binding bolts, so as to grasp the tubular arm, which, when loose, may be slid or turned in any position, and then firmly bound in that position.

The diameter of the hollow projecting arm need not be much larger than the width of the tool holder—five or six inches—in an ordinary ten inch or twelve inch machine. The sliding arm being provided with a featherway and surrounded by a graduated worm gear or ring feathered to it, the bar may be rotated to any angle and adjusted endwise without disturbing or losing the angle at which it is set. A second advantage of this arrangement would be the removal of the ordinary side projections, which so frequently come in the way when using the present machines.

I have not presented this so much to represent an improvement in shapers as to show how it is possible in machines of this class to use slides of equal length, maintain their proper position, and get adjustment of tool. But you will say it is not so simple. True. Neither is a watch as simple as an hour glass, nor a Corliss engine as simple as a Hero. Good things cost more than poor. All improvements have to be paid for. Sliding surfaces, such as those of the planing machine and slide rest of a lathe, cannot be of equal length. Then the question arises, are they made to maintain their truth as well as possible?

The table or platen of a planing machine cannot be used successfully for its entire length, unless the bed upon which it runs is longer than itself—usually about one-half longer; and when so arranged and used to any considerable extent on short work, it wears the bed concave and itself convex to fit. This would occur even were both absolutely rigid, but is much aggravated by an elastic table, which may be sprung one way or another every time a new piece is secured to it. A rigid table with wearing surfaces so generous as to always float on the oil, however heavy the load, would keep true a long time, or if the wearing surfaces were cut away toward the end of the bed, as shown by this model (see Fig. 4), the result would be practically perfect. If the slide rest of a lathe be long enough, strong enough, has wearing surface enough of the right sort, and any man has courage enough to cut away the ways on the plan just shown, one would remain true for a time far beyond anything yet produced. And so with all slides; in fact, the principle can be applied to all wearing surfaces where from necessity a short piece must work on a long guide, or a short nut on a long screw.

Journals with end play should have bearings and box of the same length. Collars, or the bosses, on wheels that resist end thrust on shafts, should rest upon or run against bosses of exactly their own diameter. The guides or slides of steam engines are as often too long as the cross heads are too short, for one is as fatal to enduring truth as the other.

I have used the best known tools to illustrate principles that are employed in all machines; the assembling or combining the sliding, the rotary, angular, and screw motions is invention or design in proportion to the extent of originality. The construction of the framing calls for the exercise of many faculties. It must be suitable, strong enough, rigid enough (entirely a different quality), of such form that the patterns can be readily made, if to be of cast metal, so as to be easily forged, if of forging, so it can be machined. And last, but not least, so it will look right—in fact, lacking nothing but the poetry to be artistic. This looks, this artistic, this good or bad, this one thing that is past reason, this thing that we can't argue about, but feel, is that part that much more can be thought about than said; that part which we may never be able to tell what to do to be right, and at most, but few things that may be depended upon as positively wrong.

Whatever nature does she does right; whatever the designer does different from what nature would do if she had the same work in hand, cannot be right. Nature at her best roots her trees to the ground, tapers their trunks, and stretches out their far-reaching branches, but the branches all combined would not exceed the trunk in size; and the branches all grow out from the trunk on one and the same plan—never two or three growing up and then one down, as we find them in some late drilling machines, but all follow the same grand plan. If there is ever an exception to this in nature it is by distortion, a deformity, an abortion. There has not yet been so many good machines designed to call for an abortion for the sake of variety, for, in fact, there have been so many abortions that the good ones make the variety.

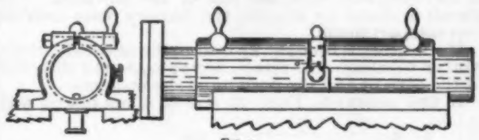


FIG. 3.

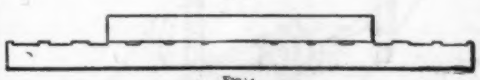


FIG. 4.

Fig. 3 shows the suggestion in regard to shaper slide, and Fig. 4 the method of cutting away the ways of a planer so as to reduce the wearing surface of the bed to the same extent as the table. In small machines the suggestion was made to cut out the spaces by milling, and in large surfaces, such as a planing machine bed, cast out the spaces and fill them with soft metal.

The causes that have been instrumental in producing such a large percentage of poor designs were these: Our early draughtsmen were architectural draughtsmen. And when the aspiring mechanic required a drawing for his new machine he employed the architect, who brought with him his ornaments and forgot the principles. His posts were columns without cornice or pediment, and when his frame, which he did not understand, did not look right, he attempted to ornament it into shape. This state of affairs was made worse by another set of draughtsmen who neither understood architecture nor mechanics, and lacked genius. Machines made from such designs have been scattered throughout the country, imitated and counterfeited, with their worst features made most prominent—cuts published in all the technical journals without a comment as to their merits or demerits in design. And now, to add to this, our colleges are going on from bad to worse by placing before their students models of motions and machines, constructed as machines never are constructed, or would not work if they were, and placing the students under a professor of drawing who teaches them how to make drawings rather than how to represent a properly designed machine, or teach them to know what constitutes good and bad designing.

The columns of all the best buildings in the world are straight—that is, their axial line. When their own weight is a considerable fraction of the whole weight, they have a considerable taper; when their own weight is but a small fraction, there is only taper enough to make them appear straight. I do not believe a computation was ever made to determine that this was right, but the designers were led to it by their own instinct. When the sides of a tapering column are perfectly straight, they will appear concave. This fact, known to the architects in Balbec days, was remedied by making the lines curved just enough so the columns looked straight. Their imitators, discovering the fact without being able to appreciate it, did as imitators usually do, magnified their discovery and mutilated a design they could not appreciate.

Take the columns of the different orders and styles of architecture—Doric, Tuscan, Ionic, Corinthian, Norman, and Gothic. No man at the present day will attempt to add to or take from in the hope of betterment, and yet the axis of every one is a straight line. No one of sense will ever attempt to improve them by making them crooked, because the straight line is right. And so with all the successful single post machine designs—they are straight. It is true that George Richards, of Manchester, gives the sides of the post a noble sweep, but the axial line of the post remains straight.

It is true the supports of a machine are subject to oblique as well as vertical strains, while the columns of a building are not. But why do we fancy that a crooked member will resist those strains better than a straight one? The reverse curve is a line of beauty—yes, in an ornament, but in a thing, not, unless there is a constructive demand for such a curve. The outline of a Porter-Allen engine bed is a reverse curve. True; and it is also true there was no room for a straight one. The noblest architecture is grand because it is consistent. Our machine designs are noble in proportion to their consistency. Every feature of every noble style of architecture is conceived in the same spirit. Every feature of a Grecian building, its columns, its openings, its mouldings, itself, were in one style, and so of the Roman, the Gothic and the Norman, and every feature of a machine design should possess the same general characteristic. The Grecian and Roman columns were round, and for the service they had to perform round was the best possible form they could be. The Gothic columns are not round usually, because for carrying the arched ribs of the vaulted ceilings, clustered columns conform to the arches and best serve the purpose. In machinery, a square or rectangular form is best, because, usually, there are things to be added, and brackets or slides are most easily attached to a flat surface. The shape is consistent, and will never be improved upon. It is one of the things no Queen Anne fashion can overthrow. Fashion follows in machinery as well as in other things, and when it follows because it is the fashion, it is more likely to follow the bad than the good. All our older mechanics can remember when the posts of an iron planing machine were formed to fit various ogee curves—that so-called line of beauty. Does that form look well to any one to-day? It has given way to the bold sweep of a single curve, which has come to stay, not simply because it looks better, but when rightly drawn it is right and looks right.

The true form is not a perfect parabola, however, because the case is not one parallel to the fixed beam loaded at one end. The planer post never gets its strain at the extreme end. We cannot trust to the mass of our mechanics to produce tasty designs, because the spirit of our people is not artistic.

The old form of framing, and that used yet by the builders of cheap machinery, is H or U section—a style supposed to be strong because the mathematicians say an H section is a strong one, but it is no stronger in any direction than the box, and infinitely weaker when subject to torsion. The patterns are costly to make and easily broken in the foundry; there are no cores to make, but lots of mending up to do. Your city is not only blessed with good designers, but with good pattern makers and founders besides. I think if a Philadelphia designer should go elsewhere, the first man he would send home for would be his old pattern maker, and the next the boss foundryman. One who has never tried it can hardly realize how little is the difference between a graceful curve and an ugly one. The man who fails to discover this difference is the one who just fails, whether as a designer or pattern maker.

If an Englishman were set to improve the German design, he would put in more iron; if the Frenchman, he would make the form more graceful; if the native Yankee, he would paint it green and stripe it with red; and to change this spirit, the example set by Philadelphia has done more than any other one thing, and it has not been so much by substituting steel-colored paint for green as the substitution of consistent things and forms for inconsistent ones, and doing the thing that was to be done in the simple, right way. This consistency comes, I believe, more from inherent common sense than education, and doing the thing right is more the result of good judgment than mathematical calculation.

It may not be possible to separate in our minds very completely machine designing from mechanical engineering, but in the sense I am endeavoring to devise rules for the one, I feel sure our colleges are entirely overestimating the importance of the higher mathematics. When one has to use his judgment whether to give a factor of safety of four or ten, his judgment will tell him about how large to make the thing any way; and in another sense, where what Oberlin Smith calls the "anvil principle" becomes an element, the figures are entirely misleading. Or, take the case of the flywheel of an engine. It is impossible to begin to figure at all until you have guessed upon the first factor—that is, what per cent. of variation in speed will you accept? For exactly uniform speed is an impossibility in an ordinary engine, and the extent of variation admissible is entirely guesswork. If you guess twice too much, your wheel will be four times too small, and so you will be twice as likely to get it what you want if you guess at the wheel and leave out the figures entirely. It is true that here and there mathematics are useful. In certain cases the higher mathematics are necessary, but usually arithmetic covers the ground, or a few marks on the drawing board, and the slide rule, is a much quicker way. When a class of forty students spend a good part of four years in learning the higher mathematics, with the certainty that at least thirty-eight of them will never have any use for them, and that the other two will forget a large part before the time for them to put them to use arrives, is it not worth questioning the real value of so much application? "Discipline the mind" may be all very well when the mind is the thing that is to do the work; but where something is to be made, the mind should never, in the sketch, the drawing, or in the mathematics, lose sight of the *thing*, to worship the methods.

For the designing of buildings, the designers, architects, receive special training; for the designing of machines, with some stingy exceptions at our colleges, no training is had, and every man does it himself.

If any one is to build a house, he employs an architect to make a plan; if we are to build a machine, none of us thinks of employing a machine designer. I have

known one exception to this. A manufacturer bought a patented invention, with nothing to show what the machine was to be but a wood model—crude in every element. He employed a man to get up some drawings of it, and with the instructions to "put it in shape." For the drawings and the putting it in shape he paid $25, and the result has been quite a fair fortune. If manufacturers would employ designers when they have machines to design as they would architects—I mean real designers, not simply draughtsmen—I believe they would find it an equally profitable investment. This would in many cases cost considerable, because competent designers are scarce, and the reason they are scarce is because, aside from the special gift, the necessary requirements are so varied.

Besides being every inch a mechanic, saturated with the courage to do things new, and right, one needs the genius of an inventor, the training of an engineer, a knowledge of architecture, the experience of a manufacturer, the skill of a master mechanic, the handicraft of many tradesmen, and the spirit of an artist.

[Continued from SUPPLEMENT, No. 643, page 10273.]

THE DIRECT OPTICAL PROJECTION OF ELECTRO-DYNAMIC LINES OF FORCE, AND OTHER ELECTRO-DYNAMIC PHENOMENA.*

By Prof. J. W. MOORE.

III. HELIX AND SOLENOID.

IF two loops are placed parallel to each other and about one-quarter of an inch apart, the field begins to resemble that of a steel bar magnet. If three or more loops be taken, the resemblance becomes still more striking.

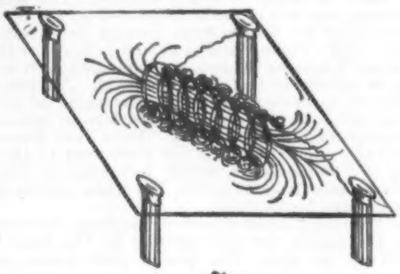


Fig. 22.

The filings arrange themselves in straight lines along the axis of the helix. At either end they diverge and reach around, to coalesce with those from the opposite pole. The curves around the vertical parts of the spirals are nearly circular.

EFFECTS PRODUCED BY A HELIX ON A RECTILINEAR CIRCUIT IN THE DIRECTION OF ITS AXIS.

Let the rectilinear circuit pass through the axis of the helix.

If the wire of the helix is returned upon itself through the axis, a true solenoid is formed. When the current passes, the lines which are transverse to the single rectilinear current disappear, and the system be-

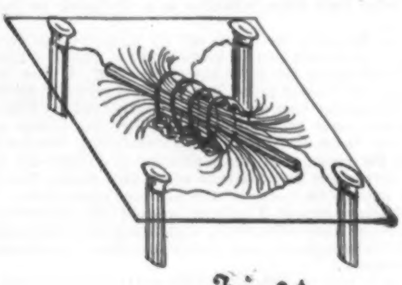


Fig. 23.

comes equivalent to a number of parallel loop currents, or parallel magnetic shells, all facing in the same direction.

To verify the above statement, a vertical astatic system (Fig. 18 *a*) is suspended from the ring stand, Fig. 9, and a solenoid placed in a vertical position parallel to one of the vertical edges; there will be neither attraction nor repulsion when a current is passed in both systems, that is, "a sinuous current is equivalent to a rectilinear current of the same length in projection." Compare Figs. 23 and 2.

If a magnet is brought end on to the helix, Figs. 24, 24 *a*, the lines of force will be gathered up or scat-

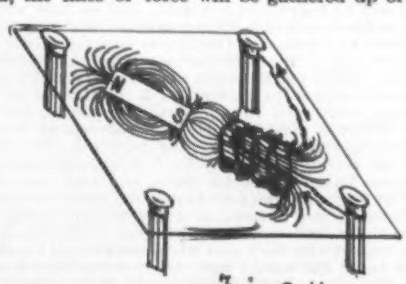


Fig. 24

tered according to the direction of the current and the position of the magnet. If the end of the solenoid faces one, and the *current flows round*, in the *direction* of the hands of a watch, the S pole will be toward the observer, just as in the case of the loop.

Fig. 24 a

To verify the above statements, a solenoid about three inches in length and one quarter of an inch in diameter (Fig. 25) is supported by two parallel threads of unspun silk from the ring stand (Fig. 9).

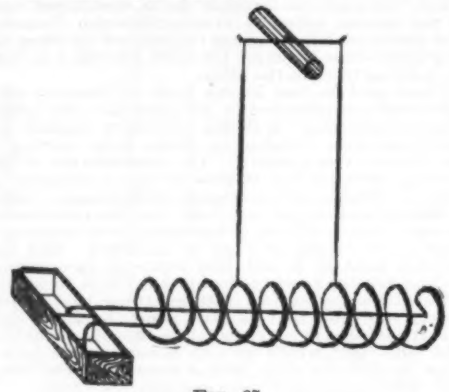


FIG. 25.

The ends of the wire dip into the partitioned trough of mercury, one on either side of the partition. The circuit is closed by dipping the battery poles into the two compartments.

If a magnet is brought up near to the solenoid, attraction or repulsion will result, according to the direction of the current and the position of the magnets.

If two solenoids, Figs. 26 and 26 *a*, are placed with

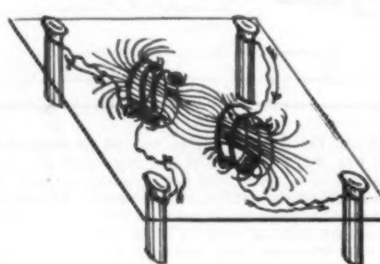


Fig. 26.

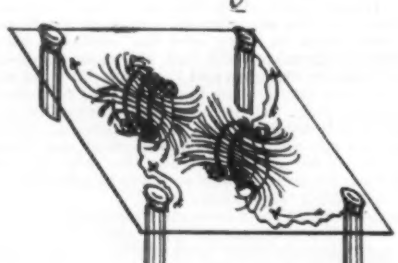


Fig. 26 a.

their poles facing, the fields become similar to those of two bar magnets similarly placed, Figs. 19 and 19 *a*.

To verify the fact, bring near to the suspended solenoid another. With like pole, there will be repulsion; if unlike pole, attraction.

Further resemblance between solenoids and magnets

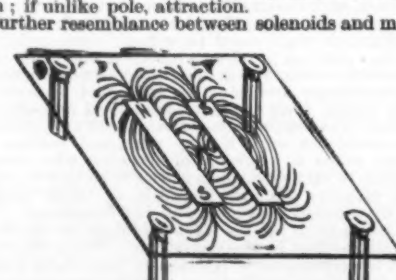


Fig. 19 b.

may be shown by arranging two bar magnets parallel to each other, as in Figs. 19 *b* and 19 *c*, and two solenoids similarly placed, Figs. 29 *b* and 29 *c*.

Where the N and S poles are opposite, attraction is shown; where like poles are opposite, repulsion; and opposite the neutral lines the flattened circles and lemniscates of 8 and 8 *a* appear.

The central part of a bar magnet gives the same field as a vertical straight conductor.

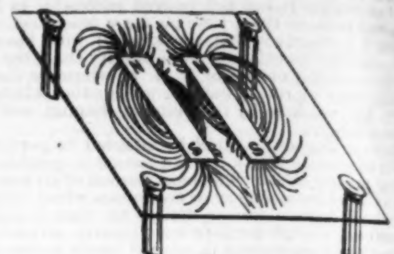


Fig. 19 c.

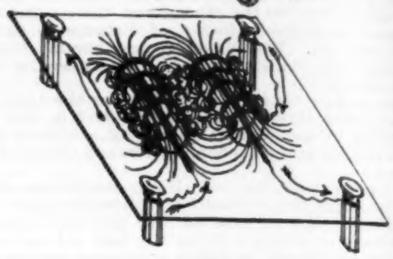


Fig. 29 b.

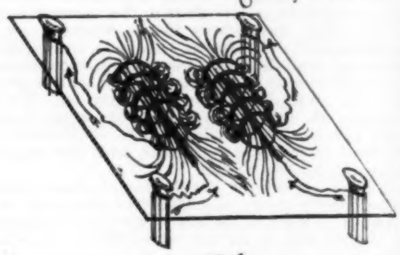


Fig. 29 c

The following collocation is also interesting (Figs 19 *d*, 19 *e*). The analogous fields may be shown with solen-

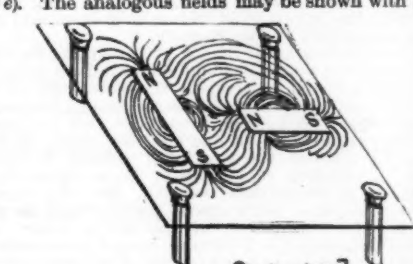


Fig. 19 d

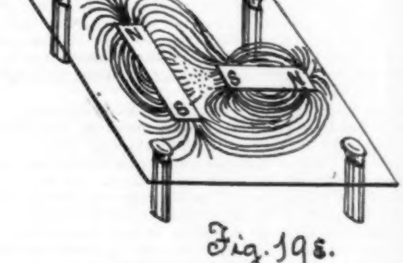


Fig. 19 e.

Fig. 29 d.

Fig. 29 e.

oids These bear a striking resemblance to Figs. 4 *b* and 4 *c*.

* An expansion of two papers read before the A. A. A. S. at the Ann Arbor meeting.

It thus becomes evident that the solenoid is practically equivalent to a bar magnet with its S pole at that end at which the current flows round in a clockwise direction.

ACTION OF THE SOLENOID.

1.—*On a Straight Wire.*

Diagrams 27 and 27 *a* are the same as 4 and 4 *a*, except that a solenoid is used instead of a bar magnet.

Figs. 27 *b* and 27 *c* are similar to 4 *b* and 4 *c*. Figs. 27 *d* and 27 *e* are like 4 *d* and 4 *e*, and 27 *f* and 27 *g* the

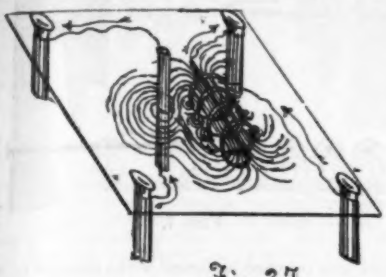


Fig. 27.

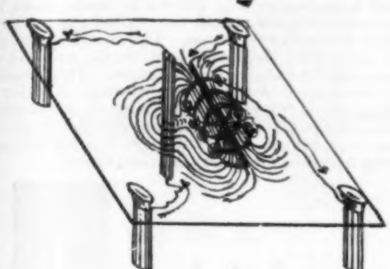


Fig. 27 a.

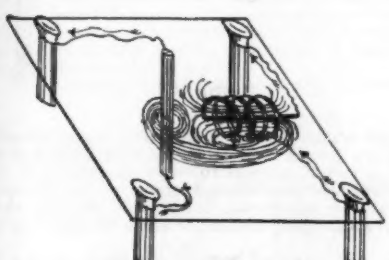


Fig. 27 b.

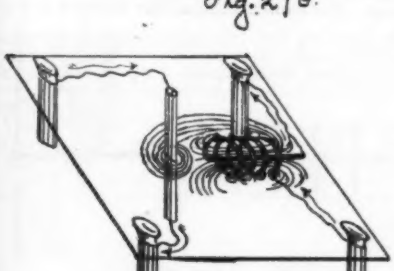


Fig. 27 c.

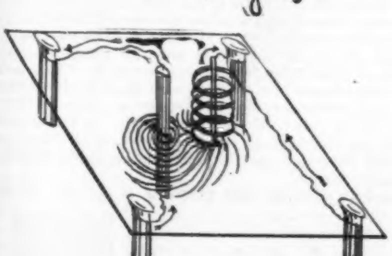


Fig. 27 d.

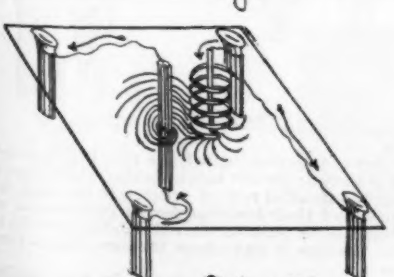


Fig. 27 e.

same as 4 *g* and 4 *h*. Fig. 27 *h* is like a solenoid with a straight current under and parallel to the axis—a horizontal view of 27 *f*.

If the straight wire is perpendicular to the axis of the solenoid and near one side, there will be attraction or repulsion, as in Figs. 8, 8 *a*.

If a solenoid nine inches in length is suspended from the modified Ampere's stand, Fig. 9, its axis will assume a N and S position through the influence of the earth's magnetism. The supposition of an infinite horizontal rectilinear current from E to W will explain the phenomenon.

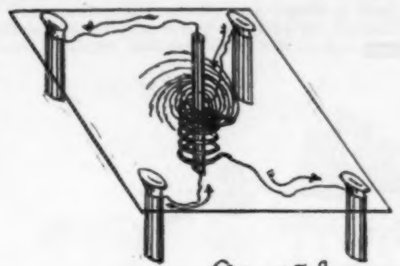


Fig. 27 f.

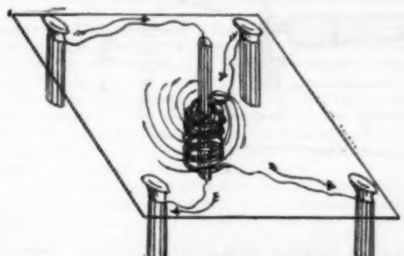


Fig. 27 g.

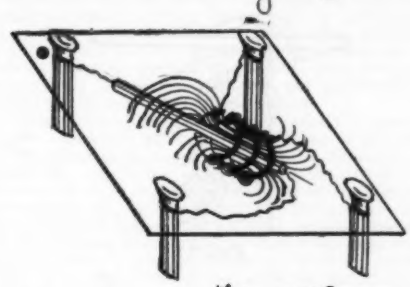


Fig. 27 h.

To verify the effects of solenoids on rectilinear currents, from the stand, Fig. 9, suspend a small solenoid, three inches in length and half an inch in diameter. Place the rectilinear circuit in various positions in reference to it.

The facts in plates 27 to 28 will then be illustrated.

2.—*On a Loop.*

In Figs. 28 and 28 *a*, a loop is placed with its axis coincident with that of a solenoid. The figures show

Fig. 28.

Fig. 28 a.

that the solenoid is like a bar magnet and the loop like a magnetic shell. The resemblance between these figures and 19 and 19 *a* is obvious.

The actual motion may be shown by carrying a solenoid near to a loop suspended from the Ampere's stand.

MAGNETIC PERMEABILITY.

After forming the field represented in Fig. 23, introduce into the helix a piece of ferrotype plate bent into the form of a half cylinder. The circular lines of force around each vertical part of the wire will be, upon tapping the plate, gathered up into the interior of the helix, the circular form disappearing.

This illustrates Faraday's idea of the conduction of the lines of force.

If a bismuth bar is introduced instead of the magnetic metal, the lines of force will seem to be repelled instead of attracted.

The action of ferro-magnetic and diamagnetic substances in a magnetic field may be shown by the following apparatus, Fig. 29.

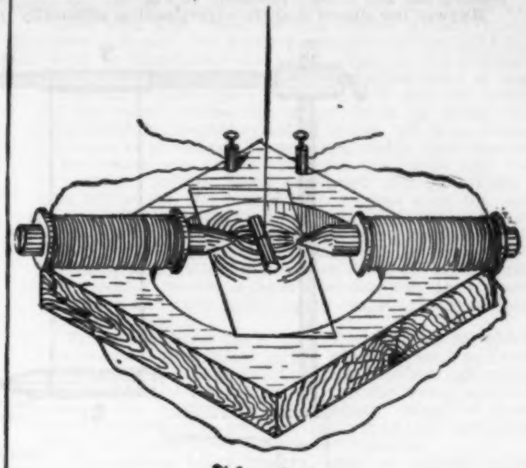


Fig. 29

The poles of two bar electro-magnets are made to project over the field of the vertical lantern; a glass plate upon which iron filings are sprinkled extends under the poles; when the circuit is closed and the plate tapped, the filings take positions along the lines of force. If a small piece of soft iron be suspended between the poles, it will place itself tangent to the "lines of force." If a piece of bismuth or other diamagnetic substance be suspended similarly, on closing the circuit it will be violently turned at right angles to the lines. By removing one electro-magnet, and suspending, opposite the pole of the other, a sphere of bismuth or other diamagnetic substance, repulsion is easily shown. The electro-magnets are made of many turns of No. 16 copper wire, well insulated. The poles are an inch apart, the cores are soft iron, 5 inches long and 1 inch in diameter, and pointed at opposing ends. Doubtless all the phenomena of magnecrystallic action may be demonstrated by the same apparatus. The general law that "the magnetic axis induced in the body coincides with the line of greatest density" may be demonstrated.

These experiments seem to show that a bar magnet, a loop, and a solenoid may be indifferently used for each other, and that when one is placed in the field of another or of a straight conductor, if free it will place itself so that the currents become parallel and in the same direction. This is true whether the currents are real or Amperean. Maxwell's rule, already quoted, will give the direction of the motion.

It must not be forgotten, however, that while a circuit can imitate a magnet, a permanent magnet cannot be made to imitate all the effects of a coil.

It is only, for example, true of the external effects that a solenoid is equivalent to a magnet.

For a hollow magnet is not equivalent to a collection of superficial currents, as may be shown by the following experiments: If a piece of steel is introduced into the interior of a helix, poles of the same name are at each extremity, but if the same piece of steel be introduced into a hollow magnet, poles of different names occupy either extremity, or if, as in Figs. 30 and 30 *a*, a

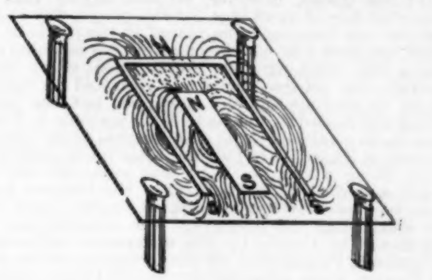


Fig. 30

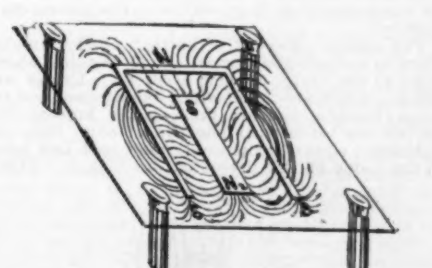


Fig. 30 a

magnet, N_2S_2, be inserted into the hollow magnet, N_1S_1, with N_2 next to N_1, repulsion is strikingly shown, while if S is similarly placed there will be unmistakable signs of attraction, the lines of force looking like ropes pulling the interior magnet further into the hollow space. See 24, 24 *a*. If a piece of soft iron is introduced into a helix, each pole will be of the same name as the corresponding end of the helix, while if the iron be introduced into a hollow magnet, each end will be temporarily opposite in name to the nearest pole of the magnet.

AMPERE'S THIRD LAW.

An attempt is made to prove Ampere's law, that "each element of a rectilinear current repels the succeeding one and is itself repelled," in Fig. 31.

Maxwell has shown that the experiment as ordinarily exhibited is an effect of induction. Here we adapt a well known apparatus to the vertical lantern. In one side of the brass ring already described a brass carbon holder (H), insulated from the ring by a vulcanite "bush" (V), is inserted. Another piece of carbon is suspended by two fine copper wires, W_1 W_2, from the horizontal support, by means of a collar (F), in such a way that the sharpened points of the carbons (C_1 C_2) may just touch. When the current passes, the free carbon is driven away from the fixed one. If the current is strong, a vibratory motion will be set up; this seems to result from the heating and cooling of the points.

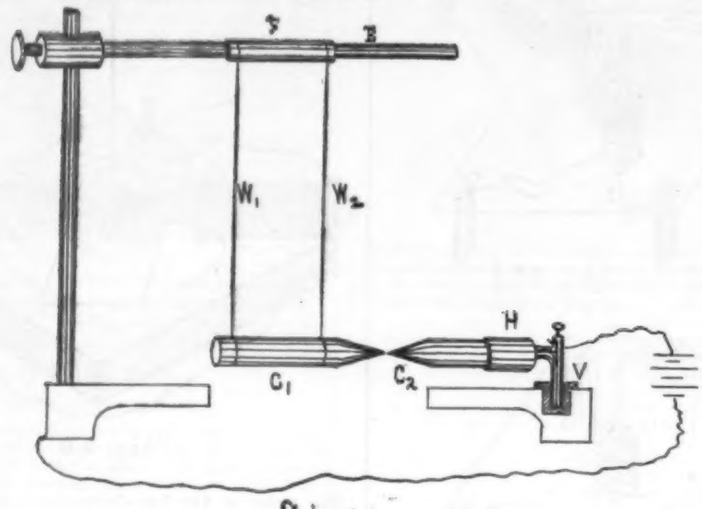


Fig. 31.

FRAMEWORK KNITTING.

By W. T. ROWLETT.

THE object of the present paper is, in the interests of technical education, to give some idea of the intricacies of the manufacture and the great need of a special technical training for those engaged in this pursuit.

The time at my disposal this evening being limited, I shall only allude briefly to the history of the stocking frame, devoting my efforts more particularly to the explanations of the various machines and processes of the framework knitting industry.

As you no doubt are aware, the stocking frame was invented in the time of Queen Elizabeth, by a poor clergyman, named William Lee, at Calverton, near Nottingham. The story relates that he sat brooding over his misfortunes, and watching his wife knit, with the baby on her knee; as he noticed her make a stocking, stitch by stitch, the idea of a machine which should do the work much more rapidly was being gradually formed in his mind. This machine I shall have the honor of describing to you later on.

After completing his machine, he applied for a patent; the Queen, however, refused, saying that the manufacture of stockings for the people was too important an industry to be placed in the power of one man, but that if he could so improve his machine as to make silk stockings, she would then grant him a patent. Lee returned home and perfected his machine so as to produce the silk stockings, but the patent being still denied to him, he took his machine to France and there established the manufacture under the protection of King Henry IV.; but after the murder of the king, being a Protestant, he was neglected, fell into want, and died in Paris in 1610. His brother, James Lee, took several frames back to England, and there he established the industry. The manufacture was continued in France by the workpeople left behind, principally Protestants, till the revocation of the Edict of Nantes, when a number of them fled into Germany, taking some frames with them, and by the end of the 17th century, framework knitting was spread over Hesse, Wurtemburg, Bavaria, Thuringia, and Saxony. This latter country is, at the present time, the strongest competitor that England has in the manufacture of hosiery.

The special property of knitted fabrics, rendering them so well adapted for articles of clothing which fit close to the body, is their elasticity. Unlike woven fabrics, which are composed of longitudinal and transverse threads, and are non-elastic, knitted fabrics proper are made with one thread only, from which horizontal rows of loops are formed, each row hanging in the loops of the preceding one (Fig. 1). This it is

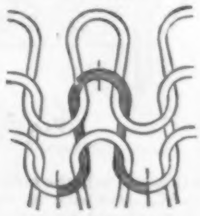


FIG. 1.

which gives the fabric its elasticity, owing to the thread being bended backward and forward continuously in opposite directions.

Figs. 2 and 3 represent a piece of hand knitting, of which you perceive the whole row of stitches are upon the one needle. To make a new row, the end of an empty needle is inserted into the first stitch and a piece of thread pulled through, while at the same time the old stitch is cast off the first needle, thus leaving the first stitch of a new row upon the second needle. This is continued stitch by stitch until the whole row is knitted off the first needle, and the new row is completed on the second one.

Instead of forming each stitch separately, Lee's idea was to form a whole row at once. To effect this, he


FIG. 2.

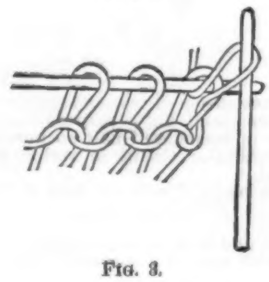


FIG. 3.

made a row of hooked or bearded needles (Fig. 4), corresponding in number to the stitches in one row, or course, as it is technically called. The hook or beard of this needle, you will observe, is long and elastic, and in the shank of the needle, just under the point of the beard, is a groove or eye, so that when the point is

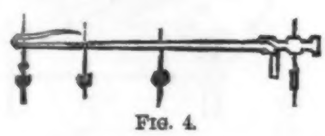


FIG. 4.

pressed down it closes the hook, and allows any loop which was upon the shank to be pushed over it. The loops are formed by a row of instruments, one to every needle, each having an independent action (Fig. 5).

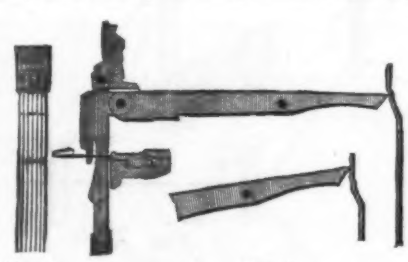


FIG. 6. FIG. 5.

These are called sinkers, and hang perpendicularly between the needles. They are jointed loosely into the ends of a set of horizontal levers called jacks. These jacks turn on a wire, which runs through the whole row, rather behind the middle of their length, and at the hinder end press against a spring with a curve in it, so that when the hinder ends of the jacks are depressed they fit in the curves, and are held in that position until released. Of course, as the part of the jack forward is the heavier, and has also the weight of the sinker upon it, the moment the hinder end is released the sinker falls. The distance through which they fall is regulated by a horizontal bar under the fore part of the sinkers, which is called the falling bar. In order to keep the jacks the proper distance apart, they are laid between the teeth of a brass comb, and the wire upon which they turn is passed through holes in them and the teeth of the comb, so as to form a succession of hinges. This comb is called the jack bar, and upon the truth and firmness of it depends the value of the frame, as this is the foundation of the frame. There is yet another important instrument required, namely, the presser, which is a straight, knife-like bar, reaching across the whole row of needles, so as at the proper moment to press down the points of the needle beards into the eyes, and thus allow the stitches to be pushed over them.

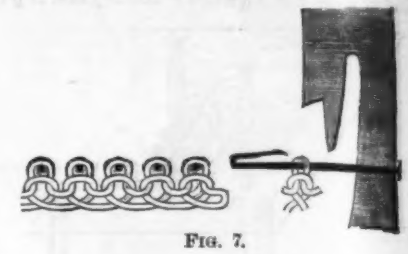


FIG. 7.

I shall now proceed to describe the manner in which these various parts are arranged, and their working.

First, the needles are cast in pairs, in a mixture of tin and lead, technically known as leads; these leads are secured on a horizontal bar, called the needle bar, by plates screwed over them. The needles must all be of the same size, thickness, and shape, and the same distance apart as their own thickness. This needle bar is the front part of the square framework which supports the whole frame. At the ends of the needle bar the two sides of the framing are carried downward, and formed into hinges, into which are jointed two arms, reaching upward, and carrying the presser.

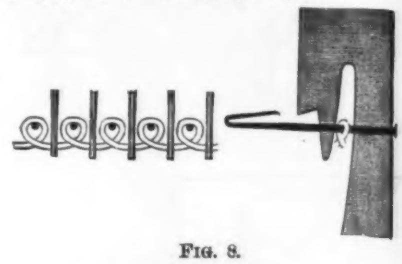


FIG. 8.

At the hinder part of the framing stand two pillars, which are joined by a cross-bar, and jointed at their upper extremities, so as to carry an axle, from which two horizontal arms reach forward, having two vertical rods at the other end, called the hanging cheeks. These two hanging cheeks are again connected by cross bars.

The jack bar and springs are fixed upon a little carriage on wheels, running upon the side bars of the framing. The sinkers hang at the forward end of the

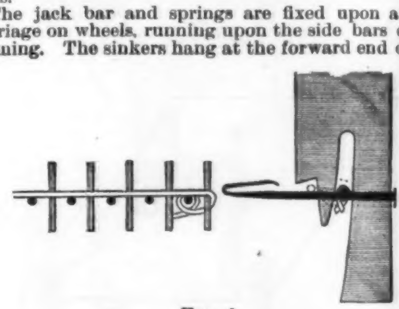


FIG. 9.

jacks, between the needles, and are held together at their lower ends by the cross bar at the bottom of the hanging cheeks, and a plate screwed in front of it.

In order to actuate the sinkers, a little carriage (Figs. 16 and 17), with a wedge shaped projection in the center, is drawn under the hinder ends of the jacks, so as to raise them one by one, and thus depress the opposite ends, which carry the sinkers. The various motions are given to the frame, partly by the hands and partly by the feet of the workman, who sits on a seat in front, forming part of the wooden stand which supports the frame.

You will observe the peculiar shape of the sinker.

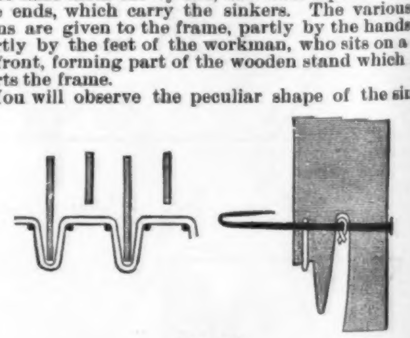


FIG. 10.

The forward portion, called the nib (Fig. 5), is for laying the thread; the slit behind, called the throat, is for taking the finished row of stitches to the back of the needles; and their lower projection on the stem, called the belly, is for pushing the old stitches over the heads of the needles, so as to draw the new stitches through them.

In commencing to work, it will be more intelligible to you if we suppose a row of stitches to be already upon the needles. The sinkers are brought forward and pressed down, so as to inclose the stitches in their throats, and then taken to the back of the needles. The drawings will show the various motions, so that you can more readily understand them.

Fig. 5 shows a side view of the needle and sinker without any work or thread upon them. Fig. 6 is a front view. Fig. 7 a front and side view of a course of stitches on the needles. Fig. 8 a front and side view

of the row after the sinkers have been raised, brought forward, lowered, and taken back again, so as to inclose the stitches in their throats, and take them to the back of the needles. Fig. 9 shows front and side views of the needles, with the thread laid across them, and under the nibs of the sinkers. Fig. 11 shows the

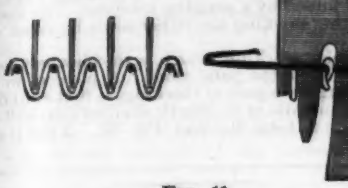


FIG. 11.

new loops sunk between the needles. Fig. 12 the new loops pushed under the needle beards, the sinker raised and brought forward, so as to bring the old stitches close to the points of the beards. Fig. 13, the beard held down by the presser, so as to bend the point into the eye and close the hook, while the sinkers are raised and brought still further forward, so as to land the old

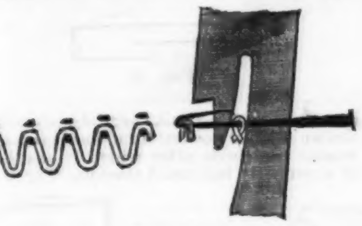


FIG. 12.

stitches upon the beards. Fig. 14, the presser raised out of the way, and the forward motion of the sinkers continued, thus completely knocking the old row of stitches over the ends of the needles, and, at one operation, pulling the whole row of new stitches through the old ones, leaving the throats of the sinkers ready to fall down, inclose the course, and bring it back to the position shown at Fig. 8.

The stitches which are made round the needles are

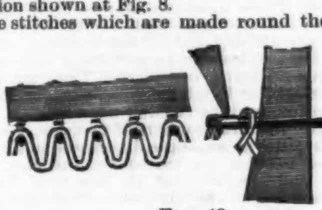


FIG. 13.

called the needle loops, and the portions of thread which lie round the sinkers, and connect the course of stitches together, are called sinker loops. It will be well to bear this distinction in mind, as I shall have to refer to it later on.

You will observe that in these motions there is a sinker attached to a jack for every needle. These are actuated by the little carriage before mentioned (Fig. 16), which is called the slurcock, being drawn under the tail of the jacks, so as to release them one by one

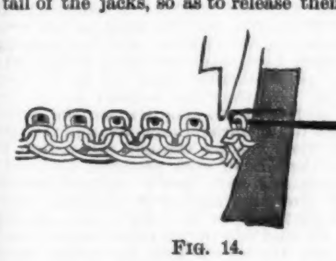


FIG. 14.

(Fig. 17). This plan answers very well for coarse work, but as it necessitates a jack for every needle, it becomes impracticable for very fine work; in practice, therefore, there is generally only a jack and an independent sinker to every other needle, so that the loops are laid as shown in Fig. 11, and not as in Fig. 10. In order to distribute these loops evenly over every needle, there is another set of sinkers hanging alternately with the jack sinkers (so called from being connected with the jacks). These are called lead sinkers, from their being cast in leads at their upper ends like the needles, and

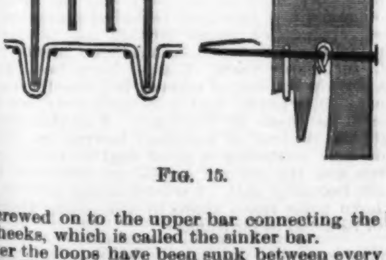


FIG. 15.

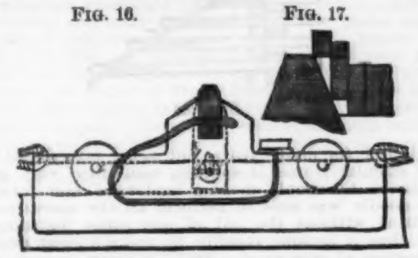
are screwed on to the upper bar connecting the hanging cheeks, which is called the sinker bar.

After the loops have been sunk between every other needle (Fig. 10), the lead sinkers are brought down bodily upon those portions of the thread stretched across over two needles, and at the same time the jack sinkers are all raised, so as to bring the nibs of both sets into a horizontal line, and thus an even row of loops is formed between all the needles (Fig. 11). This last operation not only has the advantage of enabling much finer work to be made, but it renders the machine less liable to make stitches of unequal length, as any inequalities in the laying of the loops are rendered less perceptible by their subsequent division.

In the very finest frames, there are two lead sinkers to every jack sinker, so that each loop has to be divided into three. (Fig. 15.)

The needles are usually cast two in a lead, and the gauge of the frame is indicated by the number of these leads in three inches. Thus a 30-gauge frame has 30

FIG. 16. FIG. 17.



leads or 60 needles in 3 inches = 20 needles per inch; and as the distance between the needles is equal to the thickness of each needle, it follows that it must be one-fortieth of an inch.

In order to produce good work, the edges of the nibs and bellies of the sinkers must all be exactly at the same level, also the shanks and heads of the needles. This will give you some idea of the delicacy of adjustment necessary in a stocking frame.

I have been thus particular in describing the original stocking frame, because if I have succeeded in making you comprehend its working, you will have less difficulty in understanding any other machine I have to explain, as the main principles of Lee's frame are more or less carried out in them all. I regret that there is not more time at my disposal to explain the various ingenious motions so well adapted for their particular ends in Lee's stocking frame. It is perfectly marvelous that with the limited mechanical knowledge of Queen Elizabeth's time, he should have invented a machine so nearly perfect, and which, even in my lifetime, was, with very little alteration, the principal machine used in the manufacture of hosiery.

The process I have described would, if continued, produce a piece of knitted web of equal width all down. This when sewn up would form a stocking leg, but without any proper shaping to fit the ankle. In order to fit the leg, or, in the case of a shirt, the arm, it is necessary the article should be fashioned. There are two ways of doing this without cutting the web; one is by shifting the stitches inward from each edge, so as to narrow the fabric; these are called "narrowings." The other by shifting the stitches outward, so as to widen the fabric; these are called "widenings," pronounced "widdenings."

To do this a further set of instruments, called "points" or "coverers," is employed (Fig. 18). As

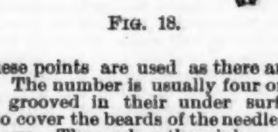


FIG. 18.

many of these points are used as there are stitches to be shifted. The number is usually four or six. These points are grooved in their under surface, and so formed as to cover the beards of the needles and fit into the needle eye. Thus, when the sinkers are brought forward, the stitches are pushed off the needles on to the points, which are then moved inward the distance of two needles, when the stitches are retransferred to the needles, leaving the two outer ones empty, and the fifth and sixth needles each with two stitches on (Fig. 19).

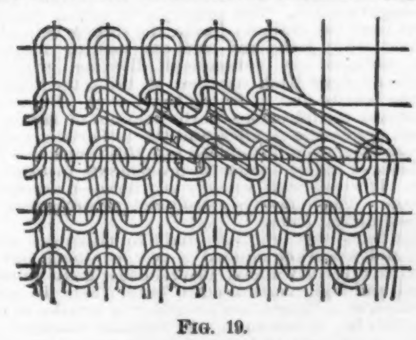


FIG. 19.

This is repeated at the other edge of the web, which is thus narrowed by four stitches.

In widening, the same instruments are used, but instead of shifting the stitches inward, they are carried outward, so as to make the fabric wider. As this makes a hole in the fabric by leaving empty needles, widening is only done by one needle instead of two at a time, and therefore requires to be performed twice as often as narrowings. There are various methods of closing the hole left in the work, but the most perfect one is that of catching the stitch which was made by the empty needle in the previous course, and placing it upon that needle, so that every one then has a stitch upon it, and the course is complete.

Up to the present I have only described the mode of producing the plain hosiery fabric, but an endless variety of stitches is made upon the stocking-frame. Of these, the most important one, next to the plain work, is the ribbed fabric, which is made by pulling certain stitches of the same course through in opposite directions. The one most generally used is called the "one and one rib," having alternate stitches pulled through in opposite directions. This fabric is extensively used for making elastic tops for the ends of socks, drawers, and undershirt sleeves; and in many cases entire articles are made of it. The machine for producing it was invented by Jedediah Strutt, of Derby, in 1755, and consists of a second set of needles upon a movable bar, which hangs in arms under the frame needles, so that the rib machine needles project upward between them, and in front of the work. When the stitches are taken to the back of the needles before commencing a new course, the machine needles are taken back with them, and the course is made in the usual manner; but when the sinkers are brought forward to knock over the work (Fig. 14), the machine needles are brought forward at the same time, so that when the stitches have been knocked over the heads of the frame needles, the sinker loops lie round the shanks of the machine needles, which are then drawn down so as to inclose these loops under their beards. The beards are pressed to close the hooks, and the downward motion being continued, the old stitches are landed on the beards and pushed over the needle heads, thus drawing the stitches through in the opposite direction to those in the frame needles. This fabric is still more elastic than ordinary framework knitting, as the alternate stitches, being pulled through in opposite directions, have a tendency to draw closer together, and when pulled apart to spring back to their original position.

There are many kinds of ribbed fabrics in which the number of stitches in the ribs vary, such as 2 and 1, 2 and 2, 6 and 2, etc., the first number indicating the number of needles together in the frame, and the second the number in the machine. Some of these are very difficult to produce, and would take too much time to explain upon the present occasion.

For making fancy hosiery, such as shawls, mitts, children's gaiters, etc., a number of supplementary apparatus are used. The first of these is the "tuck presser." You will remember the knife-like bar which presses the needle beards, to close the hooks in forming the stitch (Fig. 13). The edge of this bar is cut, so as not to press upon certain needles, whereby the stitches are knocked over some needles while both the old and new stitches are left upon others, and by varying this, patterns are produced. For example, suppose the course of stitches upon the needles to be black, and the presser to be cut so as to press the odd needles only, Nos. 1, 3, 5, 7, etc., and the new course of stitches to be made of a white thread. The black stitches would be knocked over the heads of those needles which had been pressed, and in their place would hang single white stitches of the new course, while the needles of the even numbers—2, 4, 6, 8, etc.—would have two stitches each, a black and a white one. Supposing the next course to be made of a black thread, and the presser moved sideways, so as to press those needles only which were missed in the previous course, they would have the two stitches knocked over, leaving a black stitch hanging in their place, while the needles 1, 3, 5, 7, etc., would have two stitches on. Shift the presser back to its original position, and lay a white thread again for the next course, and keep repeating these operations, laying alternately a white thread and a black thread for each course, and the result will be, not horizontal, but downward stripes of color, as the white stitches only are shown from the odd numbered needles, and the black ones from the even numbered ones (Fig. 20).

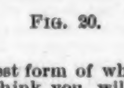


FIG. 20.

This is the simplest form of what are called "tuck patterns," and I think you will easily understand that by varying needles which are tucked, as the nonpressing is called, various figures may be produced. I will only instance one simple variation to illustrate my meaning. Take a white thread, and make one course of plain work in which every needle is pressed, then make a black course, pressing the odd needles only, followed by a white course in which every needle is again pressed. After that a black course in which the even numbered needles are pressed. This being repeated will produce a white ground with black spots upon it (Fig. 21). The next apparatus in most

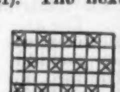


FIG. 21.

general use is the "top" machine, which is composed of points or coverers like those used in making the narrowings (Fig. 18). These points are arranged in any desired order on a bar opposite to and on a line with the frame needles, so as to take certain stitches off the needles, and transfer them to other needles, thus producing patterns in the work, with or without varying the color.

Another somewhat similar machine, the "knotted stitch" machine, works with a number of points which enter some of the stitches as they hang from the needles, and stretching them sideways, pass them on to the next needle, so that one needle has only half a stitch on, while the next one has one and a half. This makes a fabric covered with little elevations, which at one time was very fashionable for ladies' stockings.

Another very important machine is called the "Pelerine;" and, before the invention of the lace machine, it was extensively used for making point net lace. This consists of a number of points on a bar, like that which carries the needles of a rib machine (Fig. 22). These points project up between the frame needles, and when the course of stitches is knocked over, they are brought forward into the sinker loops. They are then raised up, turned horizontally, lifted above the needles, and moved sideways, so as to lay the sinker loops over the needles, thus altering the character of the work. For some patterns several of these points are bent, so as to draw the loops aside when they are raised up; sometimes two points are bent, so as to unite at the upper end, and when raised, to stretch the sinker loop, and cast it over two or more

needles. Of course, this machine is only used with very loose work, as if the fabric were made tight it would break the stitches instead of stretching them only.

Although the stocking frame marvelously increased the speed of production, the original machine, which only made one article at a time, is now out of date, and quite unsuited to the requirements of present ideas as to speed. About forty years ago, a commencement was made to build frames to make more than one at once, adding guides to lay the thread across the needles, and a machine to shift the stitches. This machine is similar to the top machine, but only has points for the edges of each division of the frame, so as to take off the stitches from both sides of all the articles simultaneously, and transfer them inward, thus narrowing all the articles at one operation. Some of these frames were built so wide as to make seven stockings at once, and required a powerful and skillful workman to manage them. As they came more extensively into use, the wages earned by the workers in frames pro-

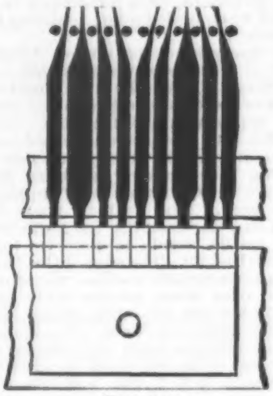


FIG. 22.

ducing only one article at once, and which could be very well managed by a lad or a young woman, were, of course, much reduced; still, some able-bodied men continued to work them, with the natural result of getting miserably paid, either from laziness or natural incapacity to work the more modern machines.

Efforts were, and are still, continually made to further increase the speed of production, and one of the results was the perfection of the circular frame, which produces a tube of work, and in which, the various motions for making the stitch being continuous, and all at work simultaneously, the amount made is greater than by any other frame, even up to the most recent inventions.

The first circular frame on record was patented by a Frenchman named Decroix, in 1798, and was followed up by Aubert, of Lyons, in 1803, and Leroy, of Paris, in 1808, who constructed one with wheels to lay the loops. Sir I. Brunel also patented one in 1816, which is the model upon which French and German circular frames are built, and for making large pieces of cloth is still held in high estimation. But the first circular frame for making tubes narrow enough for a stocking leg was built by Messrs. Paget & White, of Loughborough, some time before the year 1845. It consisted of a number of bearded needles placed perpendicularly round a tube, and having an independent up and down motion; the thread being laid between them by a number of horizontal sinkers. This machine produces very good work, and was for a long time used only by this firm.

The most popular circular frame, however, was that invented by Moses Mellor, of Nottingham, in 1848. This also has perpendicular needles standing parallel, but fixed upon the revolving circular needle bar. The thread is laid between the needles by a wheel with teeth fitting between the needles, called the "loop wheel." This wheel works upon an axle fixed separately from the frame, the teeth fitting between the needles, and is turned by the frame as it revolves, the needles acting upon the teeth in the same manner as two cog wheels work. The axle of the wheel is placed at an angle of about 45 degrees, so that as it revolves it not only carries the thread in the form of loops between the needles, but also under the needle beard. This is followed by another similar one, called the "dividing wheel," which again presses upon the loops to insure their evenness, and carries them under the needle beards right up to the heads. Next comes, inside the circle, the "landing wheel"—which pushes up the old stitches from the bottom of the needles, far enough to land them on the beards, which are pressed into the eyes just at the proper time by a plain presser wheel on the outside of the frame. The stitch is completed by another inside wheel—the "knocking over wheel"—which pushes the old stitches off the needle beards right over the heads of the hooks. A curved piece of iron, inclined downward inside the circle, takes the work down to the bottom, ready for the next course.

When these frames are made of large diameter they have several sets of wheels, each working a separate thread, so that at each revolution a number of courses are made. Both the French and English systems of circular frames are extensively employed for the Jersey cloth now so much in use, and the adoption of which has caused the introduction of this class of machinery into the cloth manufacturing districts of Yorkshire.

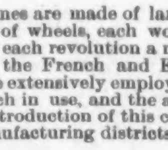


FIG. 23.

About 1858, Mathew Townsend, a hosiery manufacturer of Leicester, invented the self-acting or latch needle (Fig. 23). The object of this was to do away with the presser, which was accomplished by making the hook of the needle short and without a beard, while further down the shank was hinged a little spoon-like lever (Figs. 23 and 24), which, when turned over so that the bowl of the spoon lay on the end of the hook, shut it so as to inclose the new loop, and to allow the old stitch to slide over it (Fig. 24). This needle was

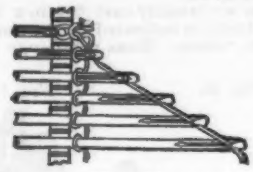


FIG. 24.

neglected for many years, but being introduced into the circular frame, it speedily came into very great favor, as by simply moving backward and forward, the needle was able to perform all the operations of knitting without the aid of any other instruments, and thus it became possible to make a great number of courses at once upon a frame narrow enough for a stocking leg. Sixteen is not an uncommon number, so that by arranging the sequence of colors fancy stripes in great variety are obtained.

We often hear the stocking loom spoken of, but this is an erroneous title, as a loom is essentially a machine which works from a warp, or set of longitudinal threads, whereas a stocking frame works with one or more transverse threads only.

Among the variations of the stocking frame, there is, however, a machine known as a warp loom, which has needles, sinkers, and presser, like a stocking frame, but all the sinkers are lead sinkers, and all come down together instead of successively, as this machine has a thread to every needle, which passes through a guide, one to each needle, whose function is to lay the loops. As a whole course of loops are laid by one operation, the working of this machine is very rapid. The fabric produced in many respects resembles the ordinary hosiery fabric, but all the threads lie perpendicularly instead of horizontally. I have said that the warp loom has a thread to every needle, but this is true only of its original form. In its development it sometimes has one thread to two or more needles, and sometimes several threads to each needle.

The variety of fabrics produced is very large, some being close and others open. A great proportion of the knitted shawls, so much worn, are made upon it, and the cloth for the white Berlin gloves worn by men servants; while it is extensively used in the lace trade for making window curtains, imitation crochet work, etc. The principle of the warp loom is especially adapted for working by power, and nearly all are now worked in this manner.

Time forbids me to do more than just glance at this important class of machines, and I must turn now to power or rotary frames, as they are called. These machines work automatically, and at first were simply a reproduction of the motions of the hand frame, actuated by levers and cams.

The first practical rotary frame was Moses Mellor's, of Nottingham, which was brought out about 1849, and copied the motion of the hand frame. Its great advantage was that it could be made so much wider, and thus produce more pieces of work at once. Its disadvantage was that it only made pieces of work the same width all down. Eventually, a top machine, worked by hand, was introduced, so as to narrow the work, and ultimately the top machine was arranged to work automatically. This machine very much resembles a large hand frame, and to a casual observer, notwithstanding all its improvements, still looks very much the same. Its most recent adaptation has been to produce ribbed work, in which form it is still in great demand.

Another class of rotary frames which has been extensively used, particularly in France and Germany, is Paget's, invented about 1855, by Mr. Arthur Paget, of Loughborough. The principle of laying the loops differs from the ordinary frame, the sinkers being independent of any jacks, and each one making a separate loop, without any subsequent dividing, while the needles all draw back together, to bring the loops under the beards, and to knock them over. But several important modifications in the manner of laying the thread across the needles, and the self-acting narrowing machine, were introduced into this frame, and form the basis of many similar improvements in other systems. It works with scarcely any noise—a decided advantage. This may be considered to have been the first self-acting frame.

This frame was originally built to make one article only, and a worker minded a row of them, but Mr. Paget has recently added several other great improvements, and has commenced to build them in several divisions, so as to produce a number of articles at once. This bids fair to become a very valuable machine.

The frame most in favor of late years is Cotton's, of Loughborough. This, like Paget's frame, is also almost noiseless. Instead of the needles being horizontal, they are perpendicular, and the sinkers are horizontal. The work comes horizontally, and the needle bar, carrying the needles, moves down and up to knock over the work, etc. Unlike Paget's frame, there are two sets of sinkers, one working with jacks in succession, the other without jacks and all together. It has also a self-acting narrowing machine, and from the lightness of its movements, can be constructed very wide. In some instances these machines make sixteen stockings at once. This frame has done more than any other to cheapen the production of fashioned hosiery, but some are of opinion that the newest Paget's frame may prove a formidable rival to it.

Both the frames last described have been adapted to produce ribbed work, but that on Paget's principle is almost unknown in this country, although it is largely used in France.

By most of these machines articles are produced in separate parts, and joined together, either by sewing or by setting portions of them on to the frame needles and then working other portions on to them. It will suffice if I describe how a stocking is made. First the leg is worked, then the heel; originally, on two separate frames. In the most recent frames the web is divided when the heel is reached, and three separate threads used, so as to make the two sides of the heel and the instep. When the heel is made sufficiently long, the two side pieces are pressed off the needles, and the center piece only continued, so as to form the upper part of the foot; this is narrowed for the point of the toe, and when finished, pressed off the needles. The sole of the foot is then made on a separate frame, either by first setting the sides of the two heel pieces upon the needles, and then working it to them, or else separately and joined by a seaming machine. The seams to complete the stocking are either sewn by hand or by machine.

The circular stocking, which is the cheapest form of all, is made from the tube alone. A piece of web sufficiently long for a pair of stockings is first cut off, and then in the middle of its length divided into half tubes long enough to form the feet (Fig. 25). A slit is cut in

FIG. 25.

the part where the half tube begins, and the latter then turned round, its end sewn into the slit so as to join it to the heel (Figs. 26 and 27), the sides being afterward sewn up to complete the foot, and the raw edge at the knee turned over inward and sewn to form a kind

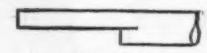


FIG. 26.

of hem. This stocking looks very shapeless until it has been drawn upon a wooden form, and pressed between two heated iron beds, after which it has the appearance of a properly fashioned stocking (Fig. 28).

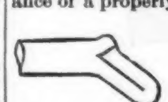


FIG. 27.

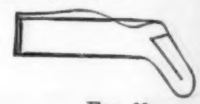


FIG. 28.

I shall not attempt to describe the various processes of dressing and finishing hosiery, as this paper is already quite long enough, but will conclude by a reference to the knitting machines which are coming extensively into use. These machines all owe their existence to Townsend's self-acting or latch needle, by means of which, as I have already said, all the necessary motions for forming the stitches can be performed without any other instruments being necessary. They are of two kinds, the straight or Lamb machine, so called after its original inventor, and the circular machine.

The "Lamb" machine consists of two sets of needles crossing each other at an angle, like those in a rib machine. These needles are raised by the cams on a straight bar, and lowered, one by one, as a thread is carried across them, so that the hooks catch it and form it into loops, while the old stitches close the latches of the needles as they slide down, and then fall on their heads, thus slipping over the new stitches, and completing the loop (Fig. 24). When both sets of needles are worked together they produce ribbed work, but when first one set and then the other are worked they form a tube, or two flat pieces of web joined at the sides. This work can be narrowed by shifting the stitches at one or both edges, and complete articles of hosiery may be made without taking the web from the needles; but all such operations are performed by hand.

The circular knitting machine is sometimes made with one set of needles only, to produce plain work; but it is generally made with two sets, one perpendicular and the other horizontal, radiating from the inside between the perpendicular ones, so as to produce ribbed fabrics. As they are worked by hand, the needles are shifted from one set to the other; or needles thrown out of action in one set, and the stitches shifted on to fresh needles brought into action in the other, so that the kind of work produced is varied. For example, in making a sock, first a one and one rib top is made with alternate needles in each set, then the stitches are transferred, so as to leave them alternately three in one set and one in the other, which produces a three and one rib for the sock leg; after which all the odd needles are taken from one-half the circumference, and the stitches transferred to the corresponding half circle of the other set, thus making a tube half plain and half three and one rib. The heel is formed out of the plain work, by moving the frame to and fro, and making stitches on certain needles only; then the whole is revolved, forming a plain sole and ribbed instep for the foot; and lastly a backward and forward motion of the plain portion makes the toe; so that when the article comes off the machine, it only requires joining at the toe to be complete.

These machines are suitable for making very useful articles, but do not produce work sufficiently good nor fine enough for high class hosiery.

I trust that my explanations have been sufficiently clear to give you some idea of the enormous scope of the framework knitting industry, and the great need those engaged in it have for a technical education. The greatest competitor Great Britain has is Germany, where technical instruction has been given in this branch for many years. Classes have been formed, with a certain amount of success, in Leicester and Nottingham. It is hoped they may ultimately become as successful as those in Germany. Unfortunately, although the subject of technical instruction is at the present time attracting a great deal of notice, manufacturers and the general public are very slow to perceive the necessity of it. I trust that the present paper may have some small share in awakening them to a sense of its great importance.

To restore the luster of dead silver work, gilt clock cases, etc., dissolve 1 ounce of cyanide of potash in 1 quart of pure water, empty it into a bottle, and label it "poison." When to be used, place the article in an earthen vessel, cover it over with the solution, and in five minutes the lusterless appearance will be removed. Preserve the fluid for future use.

HAFNER & LANGHANS' SAFETY CIRCUIT BREAKER.

THIS apparatus is designed to automatically break an electric circuit as soon as the current passes a certain limit, so as to avoid injury to any lamps or other parts in use on the circuit. The apparatus consists of two glass bulbs, *b* and *c*, Fig. 1, filled with mercury and united by a small tube, *f*. One of these bulbs communicates by the tube, *d*, with a cistern, *n*, filled with mercury. The mercury in the cistern is in communication with the binding post, *k*. The other bulb, *c*, is connected with a cylindrical reservoir, *o*, by a very small tube, *i*. The system is free to oscillate about the diameter of the bulb, *c* (Fig. 2). The second binding post is in communication with this axis of oscillation, and through it with the mercury within the bulbs.

As soon as the strength of the current exceeds a determined intensity, the mercury in *f* is heated; the heat is communicated to the mercury in *g*; as the mercury expands it rises in the tube, *i*, and begins to enter the reservoir, *o*. At this instant the center of gravity changes; the apparatus swings around the axis, d_1, d_2, and the circuit is broken when the tube, *d*, is lifted out of the mercury. It is evident that the apparatus can only work between certain limits, at intensities provided for in the calculations.—*L'Electricien.*

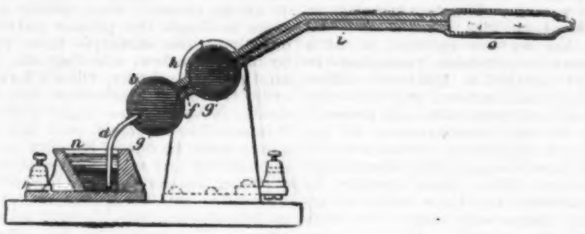


FIG. 1.

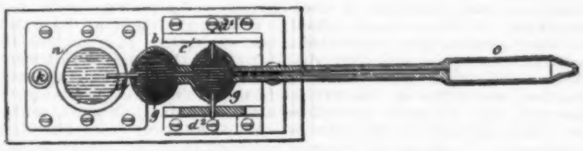


FIG. 2.

FLEXIBLE SUBSTITUTES FOR PHOTOGRAPHIC PLATES.

To photographic tourists, and to those who have to take pictures of engineering or other works while traveling, especially when it is necessary that all the photographic apparatus shall be carried in the hand, it is of value to be able to get rid of the weight of glass plates. Fifty sheets of paper, or of other flexible films, can evidently be carried with ease where fifty plates of glass of the same size would be an inconvenient burden. Each plan has its advantages and disadvantages, and the chief objection to films appears when printing from the negatives by ordinary methods. In the case of the rigid surface of the glass plate, the progress of the printing can be watched in the usual manner, and on closing the printing frame again the paper falls back on the ordinary glass negative in perfect register; whereas, with a film negative two flexible surfaces are manipulated, and the perfect register on reclosing the printing frame is not so sure. Still, when one has to travel long distances, say from London to the south of Europe, the prospect of possibly spoiling a small percentage of positives is as nothing to the disadvantage of trying to travel with a heavy weight of glass plates liable to breakage, and more liable than films to be destroyed in bulk by the over-zealous actions of exceptional custom house officials who may demand that the contents of baggage shall be exposed to daylight for examination. Although for the present professional portrait photographers adhere to glass plates, it is an open question whether to those in a large way of business films may not present certain advantages. For instance, Mr. Vergara, whose works are described farther on, states that the Stereoscopic Company and Messrs. Negretti & Zambra have each at least 200,000 negatives, which they store in boxes in rooms for which London rents have to be paid. In such instances the small space and weight of flexible films become items deserving consideration. Some large French firms think the point of sufficient importance to strip their ordinary negatives from the glass plates, after thickening the films by methods which we have not at present the space to describe in detail. To tourists, however, the pleasure or misery of a photographic trip depends largely upon economizing weight.

The Eastman Dry Plate and Film Company, of 13 Soho Square, London, manufactures new "stripping films," devised to promote lightness in out door photography. One way of overcoming the difficulty is to use paper thinly covered with sensitive gelatine emulsion, but then the resulting negative is not transparent, and has to be made more translucent by treatment with vaseline, hot castor oil, or other suitable oily substance; this in practice is anything but convenient. The new stripping film consists of a layer of insoluble sensitive gelatine emulsion upon paper previously coated with plain soluble gelatine, so that after the negative is taken it will come off its soluble support when soaked in hot water; the negative is thus quite transparent and free from grain, but has not sufficient substance to bear rough handling; consequently, the film has to be thickened. The main features of the process may be briefly summarized. The picture is brought out by means of a pyrogallol and sulphite of sodium developer, washed and fixed with thio-sulphate of soda solution, after which the film is again washed in running water, or frequent changes of water, for ten minutes. In the preceding manipulations no alum must be used in the solutions, or it would render insoluble the previously soluble substratum of gelatine.

While the films are washing, a glass plate, ⅛ in. larger all round than the negative, is cleaned and coated with an infinitely thin layer of India rubber by means of a solution of that substance. This is allowed five minutes or more to dry, after which a coating of tough collodion varnish is given. The object of the India rubber is to facilitate the stripping of the film from the glass at a later stage of the manipulations. Messrs. Eastman instruct operators to wash the collodion film well in cold water directly it sets, until the water runs from the surface without any appearance of greasiness, then place the collodion-varnished plate face upward in a dish of cold water, and bring into contact with it under water the paper negative, film side downward; grasp the plate and film by one edge with the finger and thumb, and lift the glass with the film attached slowly, allowing the water to drain from the opposite side. Lay the plate upon a table and place upon the back of the paper negative the smooth side of an India rubber "cloth" larger than the glass, and remove all surplus water by the action of a squeegee. The squeegee should be used firmly, but without violence, applying the motion in all directions. Remove the rubber cloth, lay the plate with the film upward on a table, and place upon the film a double thickness of stout, clean blotting paper. Place a board or other flat surface over the blotting paper, and on the board a weight of a few pounds. Proceed in like manner with all the washed films, always piling the last plate on the top of the blotting paper covering the previous plate, and always place on top the blotting paper, the board and the weight. In fifteen minutes the first plate will be ready to strip, but a much longer period may elapse if desired, provided the collodion varnish is not permitted to dry. The films will, however, strip perfectly after a lapse of several hours, if kept as directed. Into a flat dish put water at about 120 deg. to 200 deg. Fah.; and, face upward, in this immerse the first or bottom plate. Rock the dish slightly, and in a minute or two the paper will be found wholly or partly floating in the water. Remove it entirely with care. Remove from the film with warm water and gentle friction with a soft hair brush or the soft part of the hand any of the soluble gelatine that may remain attached. The film has then to be well washed, and cleared or intensified in the usual way if necessary; next it is well washed, and lastly, the stripping skin has to be applied. In a flat dish soak one of the stripping skins in cold water; in very dry climates soak in a bath of water containing five per cent. of glycerine and a few drops of carbolic acid. Place the plate under the skin in water and bring the skin into contact with the negative; grasp the skin by the edge with the finger and thumb and lift slowly, allowing the water to drain from the opposite side. Remove all surplus water by the gentle action of a squeegee. Set the plate aside to dry gradually, say for four or five hours, at ordinary temperatures. Trim the edges of the negative with the point of a sharp knife and strip it from the glass; a varnished negative results. Adhering India rubber solution may be removed from the face of the negative or the glass by a pledget of cotton wool saturated with benzine. It is of the utmost importance that the stripping skin should not be soaked too long—otherwise the glycerine will be entirely removed, and the finished negative will be hard and brittle; two minutes should be amply sufficient. The back of the dried stripping skin may be coated with collodion before the negative is removed from the glass if thought desirable, or if a varnished negative is not required, the use of the collodion varnish may be dispensed with entirely. Solutions used in developing the films should not exceed 75 deg. Fah., and the hands should only touch the films at the corners while wet to prevent softening of the soluble gelatine layer which holds the film to the paper.

The difficulties in the way of abolishing glass plates in outdoor photographic work have not been easy to surmount, when the same transparency and absence of structure are required in flexible films, but good work has been done by the process just described. Mr. J. G. Buchanan Wollaston, the originator of the recent exhibition at the Crystal Palace, once gave a demonstration of the process before one of the photographic societies, and exhibited a large number of first class photographs which he, as an amateur, had taken upon the Eastman stripping films.

Another method of attacking the problem of abolishing glass plates in outdoor work is to prepare transparent insoluble sheets of gelatine, and to coat them with the sensitive emulsion; thus no paper or other substance with structure is brought into play. Professor Stebbing, of Paris, some years ago made films of this kind on a commercial scale; but the samples we first tried promptly curled up in the developing dish, and remained curled, for the surfaces adhered to each other. It was evident that the two sides of film expanded unequally in water. Upon some subsequent samples specially made by him good photographs were obtained; the films did not curl up in the solutions, but expanded equally in all directions without distorting the image. Thus a half plate film gave a negative about half as large again by this unusual method of enlarging. As the expansion increased, the density of the negative decreased. A few years later, M. Balagny, of Paris, began the manufacture of gelatine flexible films, which in France have acquired considerable popularity.

In England, films made upon this principle have recently been placed upon the market by the Vergara Film Company, of Manor Road, Norwood Junction, London. The films are the invention of Mr. F. H. Froedman, of Dublin. In their manufacture, a solution is made containing gelatine, glycerine, alcohol, water, and bichromate of potash, some of which is poured upon glass previously dusted with talc powder, and coated with tough collodion, upon which the bichromated solution forms a film, which when dry strips easily. When dry it is exposed to light, whereby it becomes insoluble, then it is soaked in water, and lastly is treated with a solution of sulphurous acid to remove the last traces of color. The transparent film thus produced is of a tough and leathery nature. The Vergara company has some special camera slides of light weight made for its films, and the workmanship displayed in the making of these slides is excellent.

Fig. 1 represents the Vergara film coating machine as sketched after our examination by Mr. James Adams, who has charge of its operations. In this cut A is a firm and strong wooden table; B, a slate slab; C, driving cords; D, a glass plate in process of being coated by passing under the bars, E; F, a trough for distributing the emulsion; G, a tap; H, the hot water jacket of the gelatine sensitive emulsion vessel; J, the emulsion vessel; K, levers supporting the bars, E; O, O, O, O, spouts for conveying the emulsion to the bars, E. Fig. 2 is a section of the bars, Z, Fig. 1; these bars

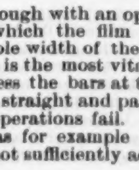
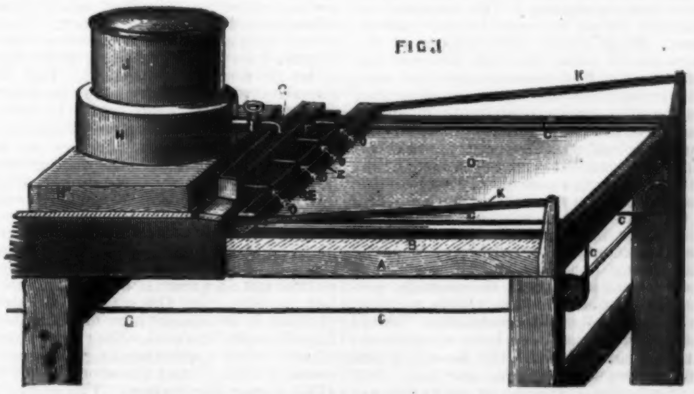


FIG. 2.

form a V shaped trough with an opening all along the bottom, through which the film of melted emulsion falls upon the whole width of the glass plate passing underneath. This is the most vital part of the whole apparatus, for unless the bars at their lower opening be mathematically straight and parallel to each other, the whole of the operations fail. What is ordinarily called "straight," as for example the edge of a good boxwood ruler, is not sufficiently accurate for the purpose.

The glass plates from which the films are stripped are 21 in. in width, and are of any length up to 46 in.



THE VERGARA FILM COATING MACHINE.

After being coated with the bichromated gelatine they are exposed for about half an hour or any longer time—for long exposure does no harm—to daylight, under the influence of which they take an olive green color. They are then soaked in pure water, to which sulphurous acid is subsequently added, to dissolve out the oxide of chromium, and to bleach the film; then, when dried, they are ready for coating with emulsion. In coating them the slit for the bichromated film is about $\frac{1}{16}$ in. wide, and for the emulsion film $\frac{1}{64}$ in. wide. When the thicknesses of the two films are properly adjusted to each other, the films do not curl in the developing operations at ordinary temperatures.

The drying of these films after the negative is finished differs from the method of drying ordinary negative

plates. Mr. F. C. Beach, a well known American photographic amateur, recently read a paper upon the Vergara films before the Society of Amateur Photographers of New York, in which he gave the following as his method and experiences about the drying operations: "After development, which usually takes about as long as a plate, the film is removed from the tray by taking hold of one corner and sliding it out on a glass plate; it is then held under the tap and washed for a minute, removed from the plate and placed picture side upward in the hypo. bath, which should not be too cold (strength, 1 oz. to 4 oz. of water); it fixes out in a few minutes, is then washed for half an hour by soaking in three or four changes of water. Unless the film is completely fixed and well washed, it will dry out with a slight yellow tinge. My first experiment in drying the film was to place it, while damp and limp, picture side upward, on a glass plate; then I set the latter in the drying rack. In the morning the film had fallen off, and was somewhat buckled up. But the rapidity of drying, as recommended by a special process, is one of the excellent points which I will demonstrate at the close of this paper. Removing the limp and leather-like negative from the wash water, slightly draining off the surplus water, you simply put it in a tray and pour over it an ounce, or less, of common alcohol, and let it soak for fifteen minutes. Before the end of that time you will notice that the film becomes quite rigid. After soaking in alcohol I place the film between two sheets of clean blotting paper, and bend them around a paper cylinder, such as is used for mailing purposes not less than three inches in diameter, so that the coated side of the film will be outward, and clamp the paper to the cylinder by two or three elastic bands. If the film is removed from the alcohol before the time specified, it will stick in places to the blotting paper. If kept in a draught of warm dry air from five to fifteen minutes, the film will become perfectly hard and dry, retaining, of course, the curve of the cylinder; but when put in a printing frame under pressure it is made quite flat, and as smooth and even as a glass plate. The buckled film negative spoken of I treated in this way, wetting it first until it was limp, soaking in alcohol, and then bending it around the cylinder; it dried perfectly flat and smooth. Fresh alcohol should be used for each separate film."

In the instructions sent out by Mr. Vergara with the films, one of the methods recommended for the drying of the finished negatives is to pass them in succession through several baths of common alcohol; the first bath, of course, soon grows weak from the water it absorbs from the films, but it gives the next bath less work to do, and so on in succession. By removing a bath when highly charged with water from one end of the series, and by placing a bath of fresh spirit at the other end, the maximum of drying work is obtained from a given quantity of alcohol.

The Balagny films, which are also of transparent gelatine, have, as already stated, become very popular in France, but have been irregularly obtainable in England. Mr. Vergara seems to be now obtaining the same results by another process, and the fact is perhaps not so generally known as it ought to be, because the first films introduced to the public by Mr. Vergara in the course of his most persevering and lengthened researches were made in another way, by saturating tissue paper with the flexible gum elemi and other hydrocarbons, a process ingenious experimentally, but possessing faults on a manufacturing scale from which transparent gelatine flexible films are free. The latter should be as well tried and tested here as those of M. Balagny have been in Paris, for at present the subject of flexible gelatine films has not been largely practically examined by photographers in this country.—*The Engineer.*

ELEMENTS AND META-ELEMENTS.

THE following address was delivered by Mr. Crookes, F.R.S., President of the Chemical Society, at the annual meeting of the Society, on the 28th of March. After reading his presidential report on the state of the Society, Mr. Crookes continued:

Permit me, gentlemen, now to draw your attention for a short time to a subject which concerns the fundamental principles of chemistry, a subject which may lead us to admit the possible existence of bodies which, though neither compounds nor mixtures, are not elements in the strictest sense of the word—bodies which I venture to call "meta-elements." To explain my meaning it is necessary for me to revert to our conception of an element. What is the criterion of an element? Where are we to draw the line between distinct existence and identity? No one doubts that oxygen, sodium, chlorine, sulphur, are separate elements; and when we come to such groups as chlorine, bromine, iodine, etc., we still feel no doubt, although, were degrees of "elementicity" admissible—and to that we may ultimately have to come—it might be allowed that chlorine approximates much more closely to bromine than to oxygen, sodium, or sulphur. Again, nickel and cobalt are near to each other, very near, though no one questions their claim to rank as distinct elements.

Still I cannot help asking what would have been the prevalent opinion among chemists had the respective solutions of these bodies and their compounds presented identical colors, instead of colors which, approximately speaking, are mutually complementary. Would their distinct nature have even now been recognized? When we pass further, and come to the so-called rare earths, the ground is less secure under our feet. Perhaps we may admit scandium, ytterbium, and others of the like sort to elemental rank; but what are we to say in the case of praseo- and neo-dymium, between which there may be said to exist no well marked chemical difference, their chief claim to separate individuality being slight differences in basicity and crystallizing powers, though their physical distinctions as shown by spectrum observations are very strongly marked? Even here we may imagine the disposition of the majority of chemists would incline toward the side of leniency, so that they would admit these two bodies within the charmed circle. Whether in so doing they would be able to appeal to any broad principle is an open question.

If we admit these candidates, how in justice are we to exclude the series of elemental bodies or meta-elements made known to us by Kruss and Nilson? Here the spectral differences are well marked, while my own researches on didymium show also a slight difference in basicity between some at least of these doubtful bodies. In the same category must be included the numerous separate bodies into which it is probable that yttrium, erbium, samarium, and other "elements"—commonly so called—have been and are being split up. Where then are we to draw the line? The different groupings shade off so imperceptibly the one into the other that it is impossible to erect a definite boundary between any two adjacent bodies and to say that the body on this side of the line is an element, while the one on the other side is non-elementary, or merely something which simulates or approximates to an element. Wherever an apparently reasonable line might be drawn, it would no doubt be easy at once to assign most bodies to their proper side, as in all cases of classification the real difficulty comes in when the harder line is approached. Slight chemical differences of course are admitted, and up to a certain point so are well marked physical differences. What are we to say, however, when the only chemical difference is an almost imperceptible tendency for the one body—of a couple or of a group—to precipitate before the other?

Again, there are cases where the chemical differences reach the vanishing point, although well-marked physical differences still remain. Here we stumble on a new difficulty; in such obscurities what is chemical and what is physical? Are we not entitled to call a slight tendency of a nascent amorphous precipitate to fall down in advance of another a "physical difference"? And may we not call colored reactions depending on the amount of some particular acid present, and varying according to the concentration of the solution and to the solvent employed, "chemical differences"? I do not see how we can deny elementary character to a body which differs from another by well marked color, or spectrum reactions, while we accord it to another body whose only claim is a very minute difference in basic powers. Having once opened the door wide enough to admit some spectrum differences, we have to inquire how minute a difference qualifies the candidate to pass.

I will give instances from my own experience of some of these doubtful candidates. 1. Two closely allied bodies differ slightly in basic powers and more decidedly also in their spectrum reactions; are they distinct entities? Probably yes. 2. Two bodies have no distinctive spectrum reaction, and differ in basicity so slightly that their separation has hitherto proved to be impossible; but they differ decidedly in the color of their oxides. Are they different? I should in this case also say yes. 3. Two bodies obtained from different minerals have no recognizable chemical difference, but there is a strong line in the phosphorescent spectrum of one which is absent in the other. What are we to say in this case? 4. An earth separated with enormous difficulty from its associates has a certain very definite phosphorescent spectrum. The addition of another body greatly intensifies one or more of the lines of the spectrum of the earth so separated, while upon the other lines in the spectrum of the same earth it has no action. Is the basis of this earth simple or compound? 5. An earth showing no difference on fractionation has a phosphorescent spectrum not materially modified by the admixture of another earth; but the residual glow of one part of the spectrum as seen in the phosphoroscope is suppressed, while that of the other is not affected. Are we not here also dealing with more than one sort of molecule? 6. Earths, apparently the same, from different minerals, behave alike chemically and spectroscopically, with the exception that a certain line in the spectrum of the one is a little brighter than the corresponding line in the spectrum of the other.

Again, where are we to draw the line? If an immediate decision were required, and a poll of the chemists in this room demanded, we should probably find the dividing lines placed in all positions among these seven cases. But to have only one rank in the elementary hierarchy, to class these obscure and indefinite bodies in the same rank with silver, and chlorine, and oxygen, and sulphur, is as manifest an absurdity as it would be to put a speck of meteoric dust upon a level with the planet Jupiter, because both may be called distinct members of the solar system. Is there no way out of this perplexity? Must we either make the elementary examination so stiff that only some 60 or 70 candidates can pass, or must we open the examination doors so wide that the number of admissions is limited only by the number of applicants? The real difficulty we encounter by unlimited multiplication of elements arises from the periodic theory. That theory has received such abundant verification that we cannot lightly accept any interpretation of phenomena which fails to be in accordance with it. But if we suppose the elements re-enforced by a vast number of bodies slightly differing from each other in their properties, and forming, if I may use the expression, aggregations of nebulæ where we formerly saw, or believed we saw, separate stars, the periodic arrangement can no longer be definitely grasped. No longer, that is, if we retain our usual conception of an element. Let us, then, modify this conception. For "element" read "elementary group"—such elementary groups taking the place of the old elements in the periodic scheme—and the difficulty falls away. In defining an element, let us take not an external boundary, but an internal type. Let us say, *e. g.*, the smallest ponderable quantity of yttrium is an assemblage of ultimate atoms almost infinitely more like each other than they are to the atoms of any other approximating element. It does not necessarily follow that the atoms shall all be absolutely alike among themselves. The atomic weight which we ascribe to yttrium, therefore, merely represents a mean value around which the actual weights of the individual atoms of the "element" range within certain limits. But if my conjecture is tenable, could we separate atom from atom, we should find them varying within narrow limits on each side of the mean.

The very process of fractionation implies the existence of such differences in certain bodies. Until lately such bodies passed muster as elements. They had definite properties, chemical and physical; they had recognized atomic weights. If we take a pure dilute solution of such a body, yttrium for instance, and if we add to it an excess of strong ammonia, we obtain a precipitate which appears perfectly homogeneous. But if instead we add very dilute ammonia in quantity sufficient only to precipitate one-half of the base present, we obtain no immediate precipitate. If we stir up the whole thoroughly so as to insure a uniform mixture of the solution and the ammonia, and set the vessel aside for an hour, carefully excluding dust, we may still find the liquid clear and bright, without any vestige of turbidity. After three or four hours, however, an opalescence will declare itself, and the next morning a precipitate will have appeared. Now let us ask ourselves, What can be the meaning of this phenomenon? The quantity of precipitant added was insufficient to throw down more than half the yttria present. Therefore a process akin to selection has been going on for several hours. The precipitation has evidently not been effected at random, those molecules of the base being decomposed which happened to come in contact with a corresponding molecule of ammonia, for we have taken care that the liquids should be uniformly mixed, so that one molecule of the original salt would not be more exposed to decomposition than any other. If, further, we consider the time which elapses before the appearance of a precipitate, we cannot avoid coming to the conclusion that the action which has been going on for the first few hours is of a selective character.

The problem is not why a precipitate is produced, but what determines or directs some atoms to fall down and others to remain in solution. Out of the multitude of atoms present, what power is it that directs each atom to choose the proper path? We may picture to ourselves some directive force passing the atoms one by one in review, selecting one for precipitation and another for solution till all have been adjusted. In order that such a selection can be effected, there evidently must be some slight differences between which it is possible to select, and this difference almost certainly must be one of basicity, so slight as to be imperceptible by any test at present known, but susceptible of being nursed and encouraged to a point when the difference can be appreciated by ordinary tests. Let us follow our atoms through another stage of fractionation. The ammonia has divided them into two groups, one of which displays just the minutest possible suspicion of greater basicity than the other. Let us repeat the first experiment again with these two groups. Again, we obtain from each a precipitate and a solution, so that we have now two precipitates and two solutions. It is evident that whereas the precipitate from the original salt was slightly less basic than that which remained dissolved, the second precipitate from the first precipitate must have its basic character still further diminished, while at the same time the second solution from the first solution must contain selected atoms of a slightly higher degree of basicity. The least basic at one end and the most basic at the other end are thus two removes each from the original; and treating them in the same way for a third time, we obtain two groups of atoms which are three removes from the center. (The intermediate groups need not be here discussed. By systematic mixings they can be made to contribute their quota to the end groups.)

By repeating this operation, not once or twice, but many hundreds of times, those atoms having a tendency to come down first always going one way, and those having a tendency to remain dissolved always going the other way, we, so to speak, educate the atoms, adding to them no fresh properties, but drawing out and giving free scope to properties that already existed, but that were previously masked. A similar absence of absolute homogeneity may possibly yet be traced in many of the "elements" if once the right reagents are selected, and if laborious chemists are to be found willing to devote years to researches barren to outward seeming. That this deviation from absolute homogeneity should mark the constitution of those molecules or aggregations of matter which we designate elements will perhaps be clearer if we return in imagination to the earliest dawn of our material universe, and, face to face with the great secret, try to consider the processes of elemental evolution.

Going back to the "fire mist," the "Ur-Stoff," of the German philosophers, or the "protyle," as, after Roger Bacon, I have ventured to call it, we see an infinite number of infinitely small ultimate, or rather ultimatissimate, particles gradually accreting out of "formless stuff" and moving with inconceivable velocity in all directions. We find those particles which approximately have the same rate and modes of movement beginning to heap themselves together by virtue of that ill-understood tendency through which like and like come together—that principle by virtue of which identical or approximately identical bodies are found collected in masses in the earth's crust instead of being uniformly distributed. One of the first results of this massing tendency is the formation of certain nodal points in space, between which occur approximately void intervals. How such nodes and spaces come to be formed we shall better be able to understand by a few very simple illustrations, choosing in the first instance, instead of ultimate atoms, living men and women. If we take any very frequented street in London, say Fleet street, at a time when the animated current runs pretty equally in two directions, and if our rate of walking is somewhat greater than the mean speed of the other foot passengers, we shall observe that the throngs on the footways are not evenly distributed, but consist of knots or groups—we might almost say blocks—with comparatively open intervening spaces.

The explanation of this unequal agglomeration of individuals is simple. Some two or three persons whose rate of walking is slower than the average somewhat retard the movements of other persons, whether traveling in the same or in the opposite direction. In this manner a slight temporary obstruction is created. The persons behind catch up to the obstruction, and so increase it, while those in front of the obstruction, hurrying on unhindered at their former rate, leave a comparatively free and open space until they, too, find themselves delayed further on by another little group of loiterers. The same process may be observed with vehicles in the carriage way of much frequented streets. Thus we find that differences in rate of movement are sufficient to arrange a multitude of moving bodies into a series of knots and gaps. In a crowded thoroughfare like Fleet street, with two opposing human currents, much regularity in the sequence of these knots and voids is not to be expected; but if the observer happens to be walking with a crowd whose constituents are traveling in the same direction, the regularity becomes more apparent; and if, as is sometimes the case, a little rhythm is infused into the steps by an accompaniment of music, the knots and gaps become so orderly that the distance between one block and an-

other, measured in yards, will be found not to differ very greatly from one end of the road to the other. If, instead of men and women, we experiment with little grains of substances of approximately equal size, but differing in specific gravity, and, mixing them in a horizontal tube with water, we set them in movement by rhythmical agitation, similar phenomena will occur, and the heavy and light powders will sort themselves in a very regular manner.

Descending to a lower degree of minuteness, we all know what occurs when an induction current is passed through a rarefied gas. Here the particles, being exempt from free will or caprice, implicitly obey the law I have attempted to illustrate, and out of infinite disorder, under the influence of the electric rhythm, sort themselves into beautiful forms of stratifications. Let us now return to our ultimate atoms, where the case, though much more complicated, is of the same character. We will suppose certain points in space where the first step in differentiation has been achieved. The ultimate particles have commenced to vibrate in their new-born energy in all directions, and with velocities ranging from zero to infinity. The law which we have traced from animated beings and coarse powders, down to the molecules of a rarefied gas, still holds good at this transcendental stage of matter, and the imagination can picture knots and voids gradually forming there as well as in Fleet street. The slower particles will obstruct the quicker, the more rapid will rush up to the laggards in front, and we shall soon have groups forming in different parts of space. The constituents of each group whose rate of vibration is not in accord with the mean rate of the bulk of the components of that group will work to the outside and be thrown off to find other groups with which they are more in harmony. In time, therefore, a condition of stability is established between the various groups, and we may call these the molecules of our present system of elementary bodies. With regard to the place where atoms come into existence, it seems to me almost certain that if their existence has had a beginning, it has begun at the very edge of the protyle, or the confines of the universe, and that their subsequent migrations have always been inward.

In dynamical language, every new position into which an atom can glide must be from a position of higher to a position of lower potential. If the atom has had a beginning, it must, therefore, have been where the potential is highest—*i. e.*, on the confines of the universe; and if it comes to an end, it must be where the potential is lowest—*i. e.*, in the center of overgrown stars; so that the extinction of the central part of a star when it becomes overgrown is that which puts a limit to the size a star can attain by attracting to itself surrounding matter. This assigning of the places where chemical atoms have their origin and where they meet with extinction seems the only—or almost the only—conclusion we can yet with confidence advance. From the above illustrations it will be seen that the constituent atoms of these molecules originally may not have been gifted with exactly the same speed or amplitude of vibration. In the molecule of a certain group let the form of energy which has for a factor what we call atomic weight be represented by the figure 35·5; it follows from the foregoing exposition—which I have endeavored to make clear—that while the great bulk of its component atoms have this atomic weight, a small percentage may vary from this figure to the extent of a decimal place, while a few others may stray as much as a whole number or two on one side or the other of the mean. The ultimate atoms whose rates are not exactly 35·5, but a little higher or lower than 35·5, will congregate around the 35·5 nucleus, forming a group whose average value will be 35·5. In like manner similar groups will be formed having the average rates of 80 and 127, while intermediate spaces will be cleared, the ultimate atoms which occupied these lone spaces being attracted to the chlorine, bromine, and iodine groupings.

These groupings represent what at present we call elements, but which I conjecture may possibly consist each of an element and of a certain number of meta-elements, or each may be formed of a whole group of meta-elements, none of which greatly preponderates over the remainder. On the threshold we encounter an objection very clearly stated by Clerk-Maxwell in his "Theory of Heat" (1871). "I do not think," says this eminent physicist, "that the perfect identity which we observe between different portions of the same kind of matter can be explained on the statistical principle of the stability of the averages of large numbers of quantities each of which may differ from the mean; for if of the molecules of some substance, such as hydrogen, some were of slightly greater mass than others, we have the means of producing a separation between molecules of different masses, and in this way we should be able to produce two kinds of hydrogen, one of which would be somewhat denser than the other. As this cannot be done, we must admit that the quality which we assert to exist between the molecules of hydrogen applies to each individual molecule, and not merely to the average of groups of millions of molecules. The molecules of the same substance are all exactly alike, but different from those of other substances. There is not a regular gradation in the mass of molecules from that of hydrogen, which is the least of those known to us, to that of bismuth: but they all fall into a limited number of classes or species, the individuals of each species being exactly similar to each other, and no intermediate links are found to connect one species with another by a uniform gradation. In the case of molecules, however, each individual is permanent; there is no generation or destruction, and no variation, or rather no difference, between the individuals of each species.

"Our molecules are unalterable by any of the processes which go on in the present state of things, and every individual of each species is of exactly the same magnitude, as though they had all been cast in the same mould like bullets, and not merely selected and grouped according to their size, like small shot." I think it evident that the statements here quoted, some of which involve no small amount of assumption, no longer accord with facts, for we actually do find variations between the properties of certain molecules which heretofore had been pronounced identical with each other. Take the case of yttrium. It had its definite atomic weight, it behaved in every respect as a simple body, an element, to which we might indeed add, but from which we could not take away. Yet this yttrium, this supposed homogeneous whole, on being submitted to a certain method of fractionation, is resolved into portions not absolutely identical among themselves, and exhibiting a gradation of properties. Or take the case of didymium. Here was a body betraying all the recognized characters of an element. It had been separated with much difficulty from other bodies which approximated closely to it in their properties, and during this crucial process it had undergone very severe treatment and very close scrutiny.

In short, until lately we might have said of it just what Clerk-Maxwell says of hydrogen, that the quality which we assert to exist between the molecules of didymium applies to each individual molecule, and not merely to the average of groups of millions of molecules. But then came another chemist, who, treating this assumed homogeneous body by a peculiar process of fractionation, resolved it into the two bodies praseodymium and neodymium, between which certain distinctions are perceptible. Further, we even now have no certainty that neodymium and praseodymium are simple bodies. On the contrary, they likewise exhibit symptoms of splitting up. Now, if one supposed element on proper treatment is thus found to comprise dissimilar molecules, we are surely warranted in asking whether similar results might not be obtained in other elements, perhaps in all elements, if treated in the right way. We may even ask where the process of sorting out is to stop—a process which of course presupposes variations between the individual molecules of each species. And in these successive separations we naturally find bodies approaching more and more closely to each other.

Dr. Auer von Welsbach, the discoverer of neodymium and praseodymium, remarks that these bodies "approximate more closely to each other than any two supposed simple bodies yet known." Thus we approach nearer and nearer either to a regular gradation in the molecules or to the recognition of those intermediate links which I have named "meta-elements" or elementoids. A suggestion here occurs that it may be to the presence of these meta-elements that so many of the chemical elements, while approaching closely in their atomic weights the values required by Prout's law, deviate from it by a small but measurable amount. We can scarcely regard their approximation as purely accidental. We now come to the last objection pertinently put forth by Clerk-Maxwell to the hypothesis that the elements are not absolutely homogeneous. He writes: "It is difficult to conceive of selection and elimination of intermediate varieties, for where can these eliminated molecules have gone to if, as we have reason to believe, the hydrogen, etc., of the fixed stars is composed of molecules identical in all respects with our own?" In the first place we may call in question this absolute molecular identity, since we have hitherto had no means for coming to a conclusion save the means furnished by the spectroscope, while it is admitted that for accurately comparing and discriminating the spectra of two bodies they should be examined under identical states of temperature, pressure, and all other physical conditions. We have certainly seen, in the spectrum of the sun, rays which we have not been able to identify. We have supposed the cosmic cycle re-entering in successive periods, during a fall of temperature, the same region—say, for instance, where chlorine, bromine, or iodine have been formed.

If most of the atoms present approximate more or less closely to 35·5, 80, or 127—the atomic weights of these three bodies—they will be in consequence easily disposed of. But there may be besides a few intermediate atoms having, say, atomic weights of between 36 and 79 and between 81 and 126. These atoms will be attracted to the masses on one side or the other of the cyclical track. We can even imagine sparse atoms scattered so far from the center line of track as to be midway between chlorine and bromine or between bromine and iodine; these wanderers likewise will be slowly picked up, and will gravitate to chlorine, bromine, or iodine; and, being thus accounted for, none need be eliminated. It is not impossible, moreover, that the elementary atoms themselves are not the same now as when first generated. For if an atom has commenced its existence at a certain epoch, and may go through such vicissitudes that it will cease to exist, it seems at least probable that it may undergo inward change. These vicissitudes probably directly affect only the primary motions which constitute the existence of the atom, but they indirectly, and only in a slight degree, affect those secondary motions which produce all the effects we can observe—chemical effects, heat effects, electrical, and so on.

Thus, while the life of an atom may be waning away under the various experiences to which it is subjected, it may and probably does appear to us the same as at first. But perhaps not quite, so that atoms originally alike, taken from different minerals collected at widely separated stations on the earth, may have had sufficiently different past histories to have come to be markedly different in regard to the primary motions which elude our observation, and through the very slight influence which changes in the primary motions have on the secondary motions, may be just perceptibly different under our experiments. From this point of view a rare element, like a rare plant or animal, is one which has failed to develop in harmony with its surroundings. This view leads itself very naturally to the facts we encounter in our fractionation experiments. Where all the ultimate atoms have precisely identical rates of vibration, any fractionation is impossible. Where such rates are not identical the process proves successful, and all the more easily the wider the differences among the vibration rates of the ultimate atoms. The bodies thus split off necessarily very closely approximate to each other, and the further we push our fractionations the less marked are the differences. But as we review the series of elements arranged on the curve I adopted from Professor Emerson Reynolds to illustrate my address on the "Genesis of the Elements," delivered before the chemical section of the British Association (Birmingham meeting), we cannot fail to be struck by a consideration which at first sight appears absolutely fatal to the notion of the production of the elements from a series of "knots," as just described.

If the element which we call aluminum has been formed from ultimate atoms having rates of vibration of the rate 27, or a little more or less, so as to give a mean of 27, and if the atoms between aluminum and the next element in the series have in this manner been sorted out to the one hand or the other, leaving a void between, we should expect that their properties would not differ very widely from each other, or at least that they would present considerable analogies. Now, to a certain extent this is actually the case. Upon aluminum follows silicon. We may perhaps conceive these two elements as springing from the differentiation of a nearly homogeneous swarm of ultimate atoms. But if we pursue the curve onward, what elements follow? Phosphorus, sulphur, and chlorine—bodies heterologous with each other and heterologous with silicon. We can scarcely imagine original atoms, so to speak, in doubt which of two aggregations they should join, the one being silicon and the other phosphorus. Nor can we conceive of anything being split off from sulphur which should make even the slightest approximation to chlorine. It appears to me, however, that these difficulties are more apparent than real. In the Birmingham address already referred to, I asked my audience to picture the action of two forces on the original protyle—one being time, accompanied by a lowering of temperature; the other, swinging to and fro like a mighty pendulum, having periodic cycles of ebb and swell, rest and activity, being intimately connected with the imponderable matter, essence, or source of energy we call electricity.

Now, a simile like this effects its object if it fixes in the mind the particular fact it is intended to emphasize, but it must not be expected necessarily to run parallel with all the facts. Besides the lowering of temperature with the periodic ebb and flow of electricity, positive or negative, requisite to confer on the newly born elements their particular atomicity, it is evident that a third factor must be taken into account. Nature does not act on a flat plane, she demands space for her cosmogenic operations, and if we introduce space as the third factor, all appears clear. Instead of a pendulum, which, though to a certain extent a good illustration, is impossible as a fact, let us seek some more satisfactory way of representing what I conceive may have taken place. Let us suppose the zigzag diagram not drawn upon a plane, but projected in space of three dimensions. What figure can we best select to meet all the conditions involved? Many of the facts can be well explained by supposing the projection in space of Professor Emerson Reynolds' zigzag curve to be a spiral. This figure is, however, inadmissable, inasmuch as the curve has to pass through a point neutral as to electricity and chemical energy twice in each cycle. We must therefore adopt some other figure. A figure of eight or lemniscate will foreshorten into a zigzag just as well as a spiral, and it fulfills every condition of the problem. Such a figure will result from three very simple simultaneous motions. First, a simple oscillation backward and forward (suppose east and west); secondly, a simple oscillation at right angles to the former (suppose north and south) of half the periodic time—*i. e.*, twice as fast; and thirdly, a motion at right angles to these two (suppose downward), which, in its simplest form, would be with unvarying velocity. If we project this figure in space, we find on examination that the points of the curves where chlorine, bromine, and iodine are formed come close under each other; so also will sulphur, selenium, and tellurium; again, phosphorus, arsenic, and antimony; and in like manner other series of analogous bodies.

It may be asked whether the scheme explains how and why the elements appear in this order. Let us imagine a cyclical translation in space, each revolution witnessing the genesis of the group of elements which I previously represented as produced during one complete vibration of the pendulum. Let us suppose that one cycle has thus been completed, the center of the unknown creative force in its mighty journey through space having scattered along its track the primitive atoms—the seeds, if I may use the expression—which presently are to coalesce and develop into the groupings now known as lithium, beryllium, boron, carbon, nitrogen, oxygen, fluorine, sodium, magnesium, aluminum, silicon, phosphorus, sulphur, and chlorine. What is most probably the form of track now pursued? Were it strictly confined to the same plane of temperature and time, the next elementary groupings to appear would again have been those of lithium, and the original cycle would have been eternally repeated, producing again and again the same fourteen elements. The conditions, however, are not quite the same. Space and electricity are as at first, but temperature has altered, and thus instead of the atoms of lithium being supplemented with atoms in all respects analogous with themselves, the atomic groupings which come into being when the second cycle commences form, not lithium, but its lineal descendant, potassium. Suppose, therefore, the *vis generatrix* traveling to and fro in cycles along a lemniscate path as above suggested, while simultaneously temperature is declining and time is flowing on—variations which I have endeavored to represent by the downward sink—each coil of the lemniscate track crosses the same vertical line at lower and lower points. Projected in space, the curve shows a central line neutral as far as electricity is concerned and neutral in chemical properties—positive electricity on the north, negative on the south.

Dominant atomicities are governed by the distance east and west from the neutral center line, monatomic elements being one remove from it, diatomic two removes, and so on. In every successive coil the same law holds good. As the mighty focus of creative energy goes round, we see it in successive cycles sowing in one tract of space seeds of lithium, potassium, rubidium, and cæsium; in another tract, chlorine, bromine, and iodine; in a third, sodium, copper, silver, and gold; in a fourth, sulphur, selenium, and tellurium; in a fifth, beryllium, calcium, strontium, and barium; in a sixth, magnesium, zinc, cadmium, and mercury; in a seventh, phosphorus, arsenic, antimony, and bismuth; in other tracts, aluminum, gallium, indium, and thallium; silicon, germanium, and tin; carbon, titanium, and zirconium; while a natural position near the neutral axis is found for the three groups of elements relegated by Professor Mendelejeff to a sort of hospital for incurables—his eighth family. We have now traced the formation of the chemical elements from knots and voids in a primitive, formless fluid. We have shown the possibility, nay, the probability, that the atoms are not eternal in existence, but share with all other created beings the attributes of decay and death. We have shown, from arguments drawn from the chemical laboratory, that in matter which has responded to every test of an element, there are minute shades of difference which may admit of selection. We have seen that the

time-honored distinction between elements and compounds no longer keeps pace with the developments of chemical science, but must be modified to include a vast array of intermediate bodies—"meta-elements."

We have shown how the objections of Clerk-Maxwell, weighty as they are, may be met; and, finally, we have adduced reasons for believing that primitive matter was formed by the act of a generative force, throwing off at intervals of time atoms endowed with varying quantities of primitive forms of energy. If we may hazard any conjectures as to the source of energy embodied in a chemical atom, we may, I think, premise that the heat radiations propagated outward through the ether from the ponderable matter of the universe, by some process of nature not yet known to us, are transformed at the confines of the universe into the primary—the essential—motions of chemical atoms, which, the instant they are formed, gravitate inward, and thus restore to the universe the energy which otherwise would be lost to it through radiant heat. If this conjecture be well founded, Sir William Thomson's startling prediction of the final decrepitude of the universe through the dissipation of its energy falls to the ground. In this fashion, gentlemen, it seems to me that the great question of the elements may be provisionally treated. Our slender knowledge of these first mysteries is extending steadily, surely, though slowly. While certain ardent chemists are testing the commonly received view of the homogeneity of the elements by methods of fractionation, others, by means of the spectroscope, are carrying on another form of assault; each worker bent on the one idea of undermining the secret. I earnestly recommend such researches. However successfully pursued, they cannot, I know, lead directly to any results capable of being turned to industrial account. If, however, we consider the small but firm foothold we have gained in pursuit of this line of investigation, I venture to think there is reasonable ground to hope that these researches may tend to place chemistry upon a new foundation, by penetrating down through loose, superficial matter to the solid rock. The application of the luminous principle of evolution has remodeled and vivified many branches of biology, and philosophers are eagerly invoking its aid in other departments of science. I would fain hope that I may not be deemed unduly sanguine in believing that the application of this regenerating principle to chemistry will produce far-reaching effects on its harmonious and progressive development.

ON THE APPEARANCES PRESENTED BY THE SATELLITES OF JUPITER DURING TRANSIT.

A PAPER was read by Mr. Edmund J. Spitta, at the November meeting of the Royal Astronomical Society, of especial interest to those who have devoted their attention to Jovian phenomena. As the paper itself is a long one, being the result of over four years' work, we must refer our readers for details to the paper itself; but, speaking briefly, the author observes that since the discovery of the satellites by Galileo in 1610, astronomers have been puzzled by their discordant appearances during transit, but more especially by the fact that these phenomena do not apply equally to all the satellites, or even in some instances to the same satellite in two successive revolutions. It appears that notably the fourth—the farthest from its primary—as it approaches the disk of Jupiter, becomes rapidly and increasingly fainter until it arrives at contact. When once on the limb, it shines with a moderate brilliancy for about ten or fifteen minutes, then becomes suddenly lost to view for another period of about the same duration, and lastly reappears, but as a dark spot which grows darker and darker until it equals the blackness of its own shadow on the planet.

The appearance presented by the second satellite, however, is entirely different, for it seems never to have been seen otherwise than pure white during transit, whereas the first and third differ yet again from the preceding two. The former is sometimes a steel gray, and at others a little darker, whereas the latter has been seen perfectly white, and yet so black as to be mistaken for the fourth. Both appearances have been witnessed by Maraldi as far back as 1707, and that, too, in successive revolutions.

The author seems to have spent some years in examing these phenomena on all possible occasions, and under different conditions, such as before, during, and after opposition, and to have collected all published and unpublished observations, and also to have devised an occulting eye piece—movable shutters in the focus of a Ramsden eye piece—for the express purpose of shutting off the light of Jupiter, but, to use his own words, "without adding to the pre-existing knowledge of the subject."

The fact of having witnessed, when on the banks of the Rhine in 1886, the transit of a brilliantly illuminated ship's lantern as a dark spot on the disk of the rising full moon, suggested the carrying out of a series of experiments to ascertain the proportions of light which two bodies must possess, so that the smaller should appear gray or black when superimposed on the larger; and it was hoped that if the facts and figures thus experimentally obtained corresponded with the albedos of the satellites themselves as compared with Jupiter, it would not be unreasonable to suspect that the abnormal appearances presented by the satellites depended on functional idiosyncrasies of the eye itself, rather than upon physical peculiarities of the Jovian system.

Space will not allow a description of the experiments, which were somewhat numerous, the photometer employed being an adaptation of that arranged by Prof. Pritchard, of Oxford; but, speaking in short, small disks of different tintings of Indian ink, representing the satellites, were superimposed on larger ones of various sizes of pure white cardboard, and it was found that, with certain restrictions, the difference of albedo (a term expressing "the relative capacity for reflection of diffused light from equal areas") between the smaller and the larger caused the gray and black appearances, and that they were not due to any difference in the *quantity* of light reflected from either. For a moon to appear gray or black, a difference of albedo was required of 0·42 in the first case, and of 0·87 in the second, while moons of a superior albedo remained white during transit.

Further, the effect of one moon approaching another was gone into, and the fading of the smaller was likewise found to be in direct proportion to the relation its albedo bore to that of the greater, and was in no way connected with the *amount* of light reflected by either. The effects in the appearance of the same little moons when in transit over different portions of a sphere were also studied, and, strange as it may seem, *the whole of the phenomena of the dark transit were thus accidentally reproduced*, and this caused much surprise, seeing it was brought about by such simple means. The concluding experiments consisted in photometrically ascertaining, for the first time, the reflective ability of different portions of an unpolished sphere, and the results obtained are set forth in the following abridged table, column one giving the exact angle of the observation, and column two the resulting albedo:

30°	0·735
40°	0·500
50°	0·367
60°	0·323
65°	0·261
70°	0·172
75°	0·133
80°	0·080
83°	0·049
86° 30′	0·027

A large number of facts and figures having been ascertained, attention was then directed to obtaining the relative albedos of the real satellites themselves as compared with Jupiter. The reduction of the observations was attended with several difficulties, each of which had to be dealt with, but one of them especially deserves a passing mention, and it is this, viz., that the eye does not seem to be impressed in the photometer with the light coming from an object of sensible area, such as Jupiter, to the same extent as it is from a point of light such as is shown by the satellites. A suggestion from Capt. Abney, however, relieved the difficulty, and, this systematic error removed, the results came out in an extremely satisfactory manner, for it was then found that the albedos of the satellites corresponded very approximately with the requirements of the experiments, as the following abridged table shows. In column one is shown the number of the satellite, in column two its difference in magnitude with that of Jupiter, and in column three the resulting albedo:

I.	8·12	0·656
II.	8·40	0·715
III.	7·88	0·405
IV.	8·73	0·266

Thus is it shown to be more than probable that the reason the fourth satellite is uniformly black during transit, when it has passed its period of disappearance, is owing to its albedo being so low as to grant the difference between it and the background necessary for a body to appear black when superimposed on another as ascertained by the experiments. Its preliminary whiteness and disappearance are also shown to be a question of relative albedo, for they are due to the fact that a sphere at its limb and edges loses so much in reflective ability that, up to that moment, the satellite possesses sufficient albedo (as compared with the background in that situation) to maintain its whiteness. So, too, with the second satellite. Its albedo proves to be so high that it is capable of preserving its brilliancy throughout the entire transit. The third and first satellites evidently possess sides of differing albedo, one high enough to maintain a brighter aspect than the other, or even, as in the case of the third, to make it appear white when one side is presented to the earth, and dark when the other. In conclusion, to quote from the original paper, "it is not unreasonable to conclude that these anomalous phenomena are due to functional idiosyncrasies in the eye itself, rather than to physical peculiarities of the Jovian system."—*Nature.*

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